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TECHNICAL REPORT ATC-86-4

# RED RIVER U-FRAME LOCK STRUCTURE ANALYSES COMPARISON

by

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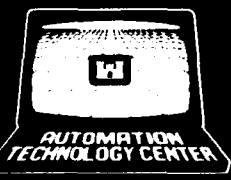
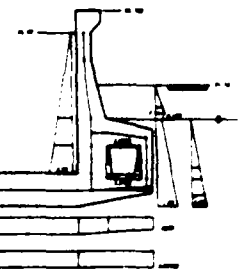
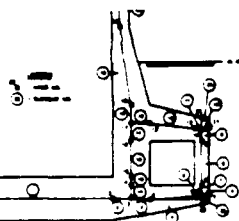
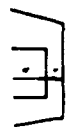
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REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER Technical Report ATC-86-4	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) RED RIVER U-FRAME LOCK STRUCTURE ANALYSES COMPARISON		5. TYPE OF REPORT & PERIOD COVERED Final report
7. AUTHOR(s) Sankar C. Das                      Kevin Abraham Robert L. Hall                     Chris A. Merrill		6. PERFORMING ORG. REPORT NUMBER
9. PERFORMING ORGANIZATION NAME AND ADDRESS Tulane University, New Orleans, Louisiana 70118 and US Army Engineer Waterways Experiment Station, Automation Technology Center, PO Box 631, Vicksburg, Mississippi 39180-0631		8. CONTRACT OR GRANT NUMBER(s)
11. CONTROLLING OFFICE NAME AND ADDRESS US Army Engineer District, Vicksburg PO Box 60 Vicksburg, Mississippi 39180-0060		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)		12. REPORT DATE May 1986
		13. NUMBER OF PAGES 121
		15. SECURITY CLASS. (of this report) Unclassified
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE
16. DISTRIBUTION STATEMENT (of this Report)  Approved for public release; distribution unlimited.		
17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)		
18. SUPPLEMENTARY NOTES Available from National Technical Information Service, 5285 Port Royal Road, Springfield, Virginia 22161.		
19. KEY WORDS (Continue on reverse side if necessary and identify by block number) GTSTRUDL (Computer program) (LC) Red River Lock (La.) (LC) U-frame locks (WES)		
20. ABSTRACT (Continue on reverse side if necessary and identify by block number) This report presents a comparative investigation involving the results of the structural analyses of a simplified frame model with beam elements and a detailed plane-strain finite-element model of a U-frame lock on the Red River. The GTSTRUDL computer program was utilized for this investigation. The study was scheduled on request of the US Army Engineer District, Vicksburg, and the structural dimensions and various loading cases were provided by this  (Continued)		

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20. ABSTRACT (Continued).

Corps office. To aid with the study, the District made available the program runs of the planar rigid frame model of the U-frame for these load cases.

These comparisons reveal the points in each analysis that have not been considered, those that are and are not in agreement, those that may not be justified, and facts that do not appear to be correct.

The importance of further investigations involving analysis of the linearly elastic U-frame structure on elastic foundation has stemmed from this study. Research into elasto-plastic foundation and dynamic soil-structure interaction effects are other related areas open for the authors' expertise.

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## PREFACE

This report presents a comparative investigation of a U-frame structure using the results of a planar rigid-frame analysis and a detailed plane-strain finite-element model. The U-frame structure used for this comparison is Lock No. 3 on the Red River, presently being designed by the US Army Engineer District, Vicksburg. The structural analysis package GTSTRU DL was used to perform the finite-element analysis and the initial frame analysis. The program CUFRAM, developed by Dr. William Dawkins under the Computer-Aided Structural Engineering (CASE) project, was used to provide a further comparison. The structural dimensions and load cases were provided by the US Army Engineer District, Vicksburg.

The planar rigid-frame analysis using GTSTRU DL was performed by structural engineers at the Vicksburg District. The finite-element grid used in this study was prepared by Messrs. Kevin Abraham and Chris Merrill, Computer-Aided Design (CAD) group, Automation Technology Center (ATC), US Army Engineer Waterways Experiment Station (WES), Vicksburg, Miss. Moment and shear calculations were performed by Mr. Abraham using the computer program CSMT. The finite-element run was accomplished and the initial report was prepared by Sankar C. Das, Associate Professor of Civil Engineering, Tulane University. The report was revised by Dr. Robert L. Hall, formerly with the Research Group, Scientific and Engineering Applications Division (SEAD), ATC, WES, under the general supervision of Mr. P. K. Senter, Chief, SEAD, ATC, WES. Dr. Hall managed and coordinated the work with Mr. C. C. Hamby being the point of contact with the Vicksburg District. Working closely with Dr. Hall during the period of report preparation and publication were Meses. Gilda Shurden and Frances Williams, editor and editorial assistant, Publications and Graphic Arts Division, WES. Dr. N. Radhakrishnan was Chief of the ATC, WES.

COL Allen F. Grum, USA, and Dr. Robert W. Whalin were Director and Technical Director, respectively, of WES during the finalization and publication of this technical report.

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CONVERSION FACTORS, NON-SI TO SI (METRIC)  
UNITS OF MEASUREMENT

Non-SI units of measurement used in this report can be converted to SI (metric) units as follows:

<u>Multiply</u>	<u>By</u>	<u>To Obtain</u>
feet	0.3048	metres
inches	2.54	centimetres
kips	4.448222	kilonewtons
kip-feet	138.255	kip-newtons
kips per square foot	47.88026	kilopascals
pounds per cubic foot	16.01846	kilograms per cubic metre
pounds per square foot	4.882428	kilograms per square metre



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## RED RIVER U-FRAME LOCK STRUCTURE ANALYSES COMPARISON

### PART I: INTRODUCTION

1. Plans are underway for the Red River Lock, a reinforced concrete U-frame structure, to be located about 150 miles north of Baton Rouge. Contrary to the conventional lock, the U-frame lock is constructed as a monolithic unit, and may be founded directly on the subsoil without piles. The structure will be a reinforced concrete U-frame having a useable chamber, 84 by 685 ft,\* with a wall height of 59 ft, and a base slab, 12 ft thick. The half section of the would-be structure is shown in Figure 1.

#### Purpose

2. The purpose of this investigation is to compare the results of the structural analysis of the simplified frame model involving beam elements with that of the detailed plane-strain finite-element model (FEM) of the U-frame using GTSTRU DL computer program. The US Army Engineer District, Vicksburg, requested this study and has provided the structural dimensions, various loading cases involving base soil-pressure, side soil-pressure, and water-pressure diagrams. The District has also made available the GTSTRU DL computer program runs of the planar rigid frame model of the U-frame for the various load cases.

#### Simplified Frame Model

3. The simplified mathematical model of the Red River U-frame involving beam elements and a few rigid links has been furnished by the Vicksburg District and is shown as the half section in Figure 2. The model involves 24 nodal points and 24 members. Members 1 through 22 are beam elements; members 23 and 24 are rigid links (Gamble 1977). Three different combinations for load conditions have been included in this study:

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\* A table of factors for converting non-SI units of measurement to SI (metric) units is presented on page 3.

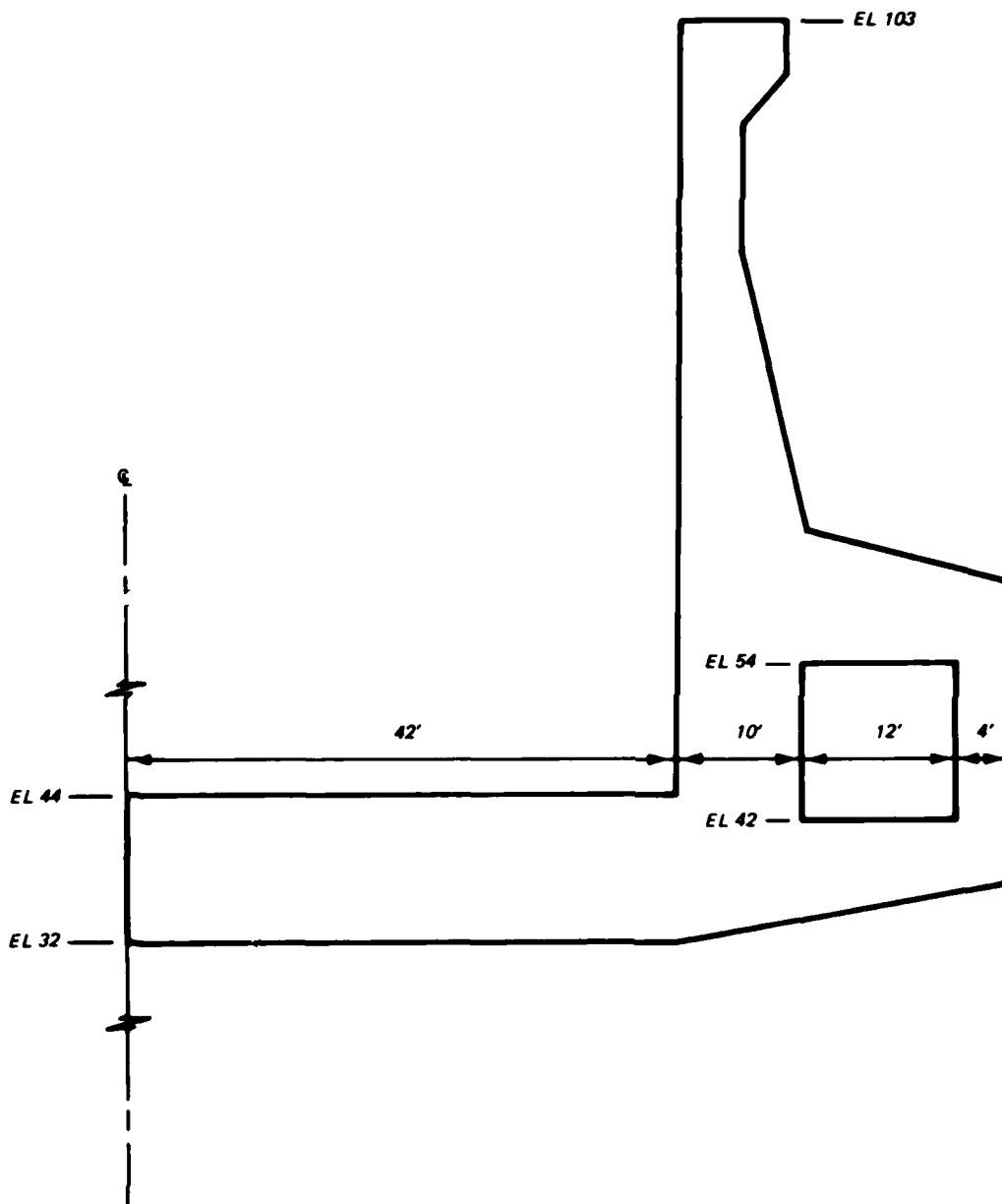


Figure 1. Half section of Red River U-frame

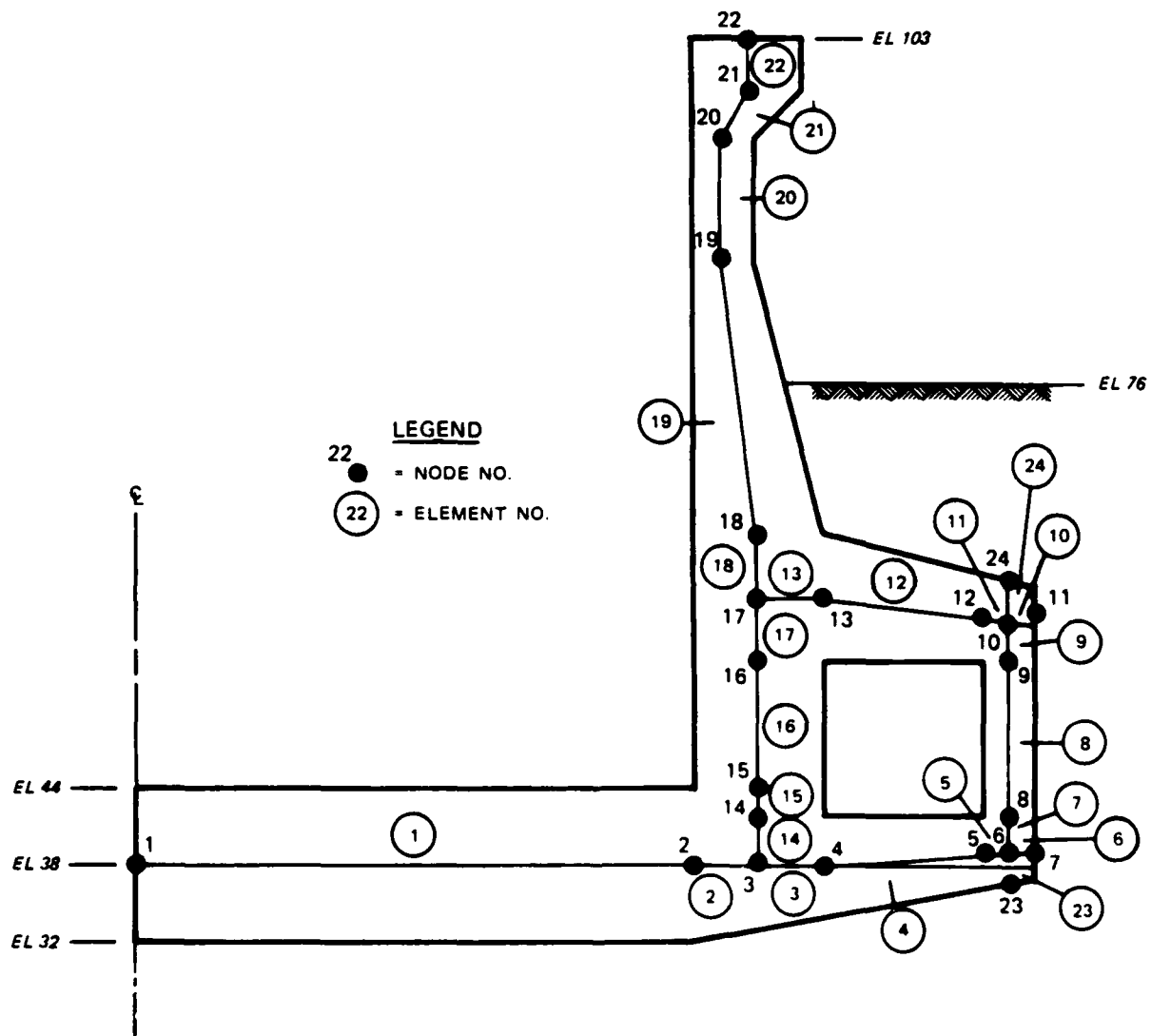


Figure 2. Simplified frame model of the half section for the U-frame

- a. Construction with backfill conditions--Case 1B.
- b. Normal operating condition--Case 2B.
- c. Extreme maintenance condition--Case 5A.

4. The vertical base soil-pressure, horizontal side soil-pressure, and water-pressure diagrams for the above load cases are shown in Figures 3 through 5. The unit weight of water, compacted soil, and concrete used are 62.4 pcf, 130 pcf, and 150 pcf, respectively. The Young's Modulus of concrete used is  $3.51 \times 10$  psi.

5. The planar rigid-frame analyses using beam-column elements were completed by the US Army Engineer District, Vicksburg. The analyses provided nodal-point displacements, axial and shear forces, and bending moments at each member joint for the three load combinations. These analyses were performed using GTSTRUDL.

#### Detailed Plane-Strain Finite-Element Model

6. The detailed finite-element mathematical model of the Red River U-frame involving plane-strain isoparametric elements has been developed at the US Army Engineer Waterways Experiment Station (WES), Vicksburg, Miss., and is shown in Figure 6. The model uses 974 nodal points and 280 plane-strain isoparametric quadratic quadrilateral (IPQQ) elements (Georgia Institute of Technology 1983). The Young's Modulus of Concrete and Poisson's ratio used are  $3.51 \times 10$  psi and 0.2, respectively. Three computer runs for this plane-strain FEM were performed for the three different load cases as shown in Figures 3 through 5. At present, GTSTRUDL does not have the capability to apply the edge pressure on the IPQQ elements in the global projected direction. Because of this deficiency all the vertical base pressures, due to soil and water on the inclined surfaces, were transformed from a global direction into a local coordinate direction.

#### Analyses Performed by GTSTRUDL

7. The complete analyses, involving nodal-point displacements; stress components,  $\sigma_x$ ,  $\sigma_y$ , and  $\tau_{xy}$ , for the various elements at the nodal points for the three different load cases as mentioned before, have been performed using GTSTRUDL computer program. The above stress components at the

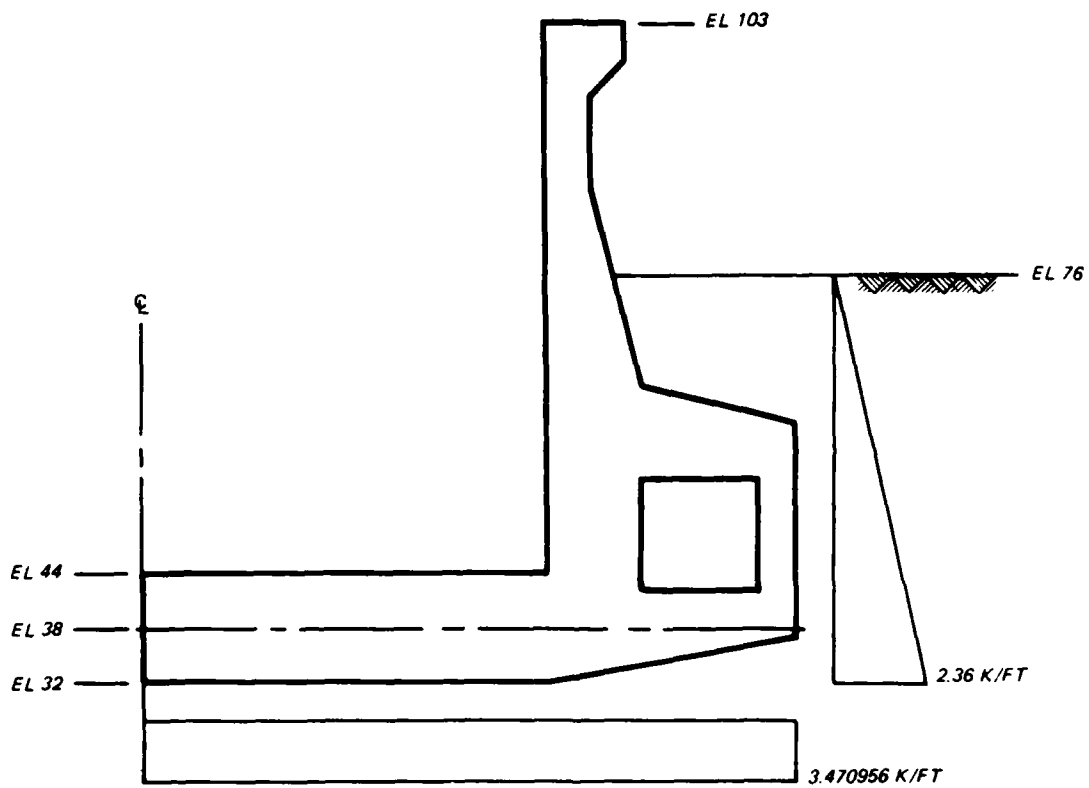


Figure 3. Load case 1B (without earthquake)--construction with backfill

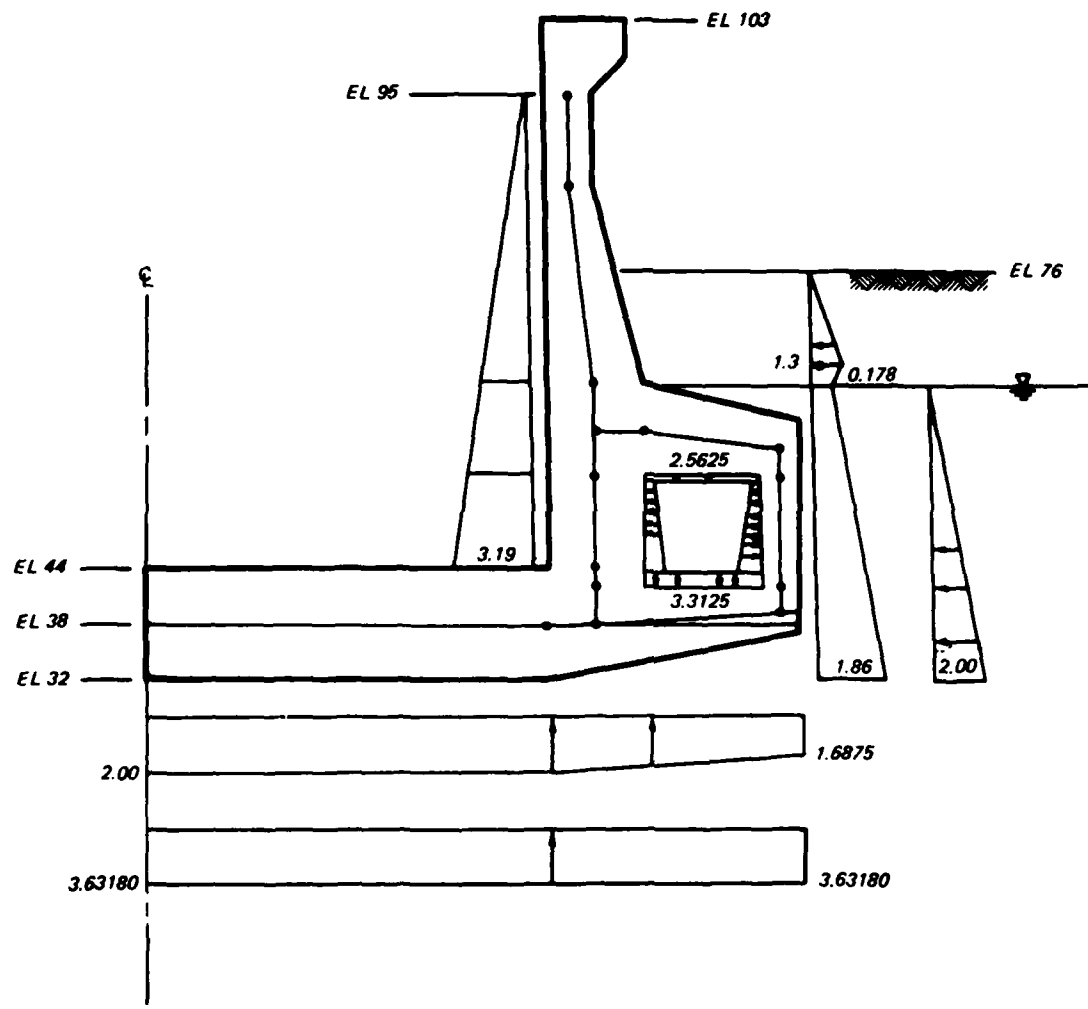


Figure 4. Load case 2B--normal operating condition

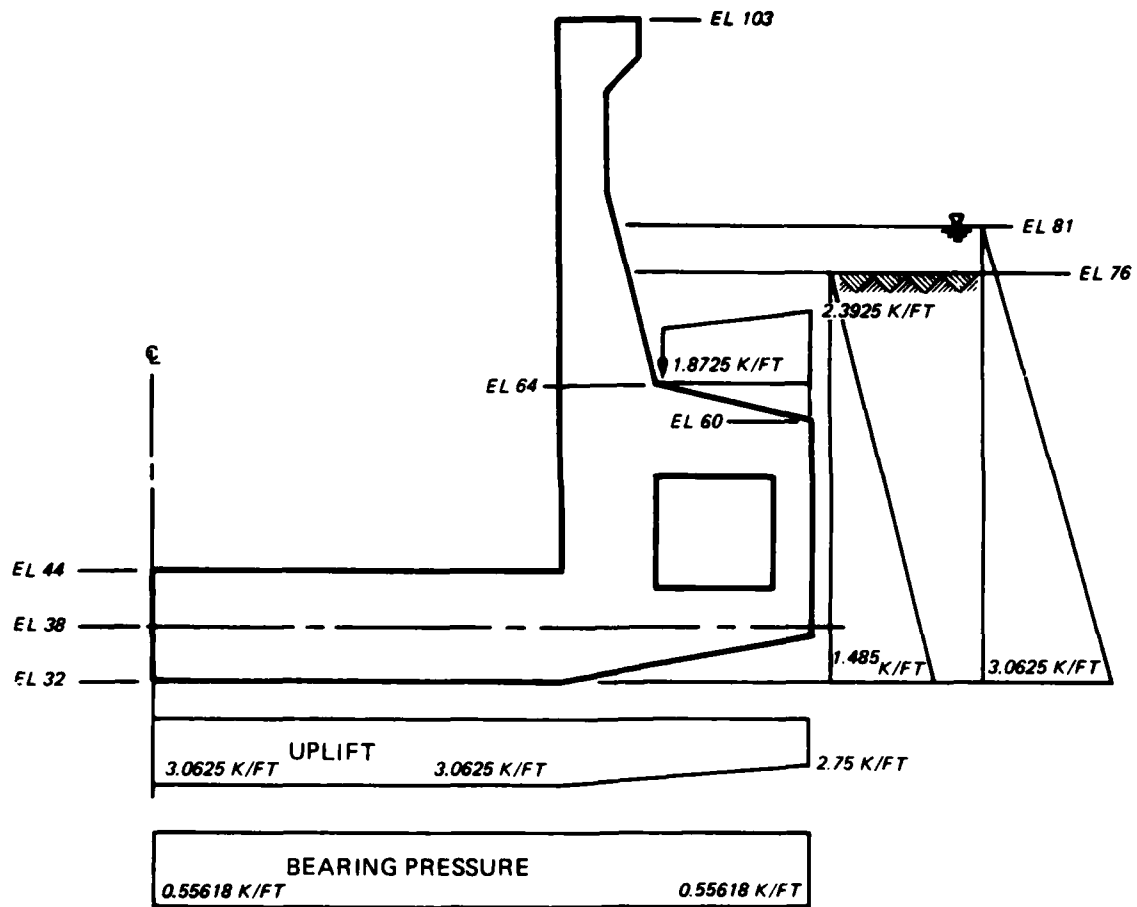


Figure 5. Load case 5A--extreme maintenance



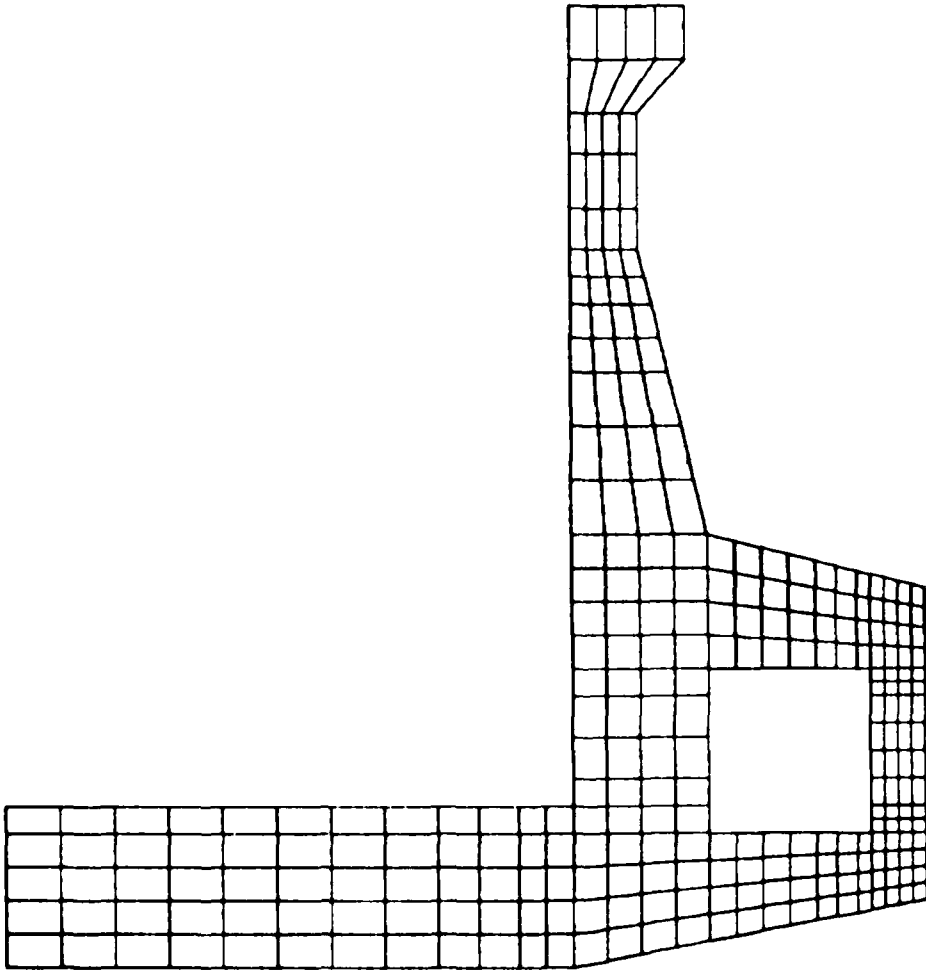


Figure 6. Detailed finite-element mathematical model of the Red River U-frame

various element nodes were used to calculate the average internal forces, axial and shear, and bending moments at the various sections of the U-frame using in-house developed computer program CSMT (Tracy, Hall, and Trahan 1983). The program CSMT calculates shear, moment, and axial forces for sections of a structure specified by the user, from stress results of a two-dimensional finite-element (FE) analysis. The bulk of the input is for geometry definition and the stress results from a FE analysis. The node and element data are read free field from one data file, and the stresses are read from another file. The remaining data are interactive commands to specify section information to obtain plots of grid, sections, and the results (shear, moment, and axial forces).

## PART II: RESULTS

### Joint Displacements

8. The joint displacements for the various nodal points (Figure 2) from the frame analysis using beam-column elements and the detailed plane-strain FE analyses were compared for the three different load cases, are shown in Tables 1 through 3. The percent difference between the displacements predicted by these two models is less than 5 percent, except for the horizontal displacements along the base slab. These horizontal displacements are two orders of magnitudes less than the vertical displacement and, therefore, do not result in a misrepresentation of the structural behavior. The graphical representation of the base-slab deflection and the wall deflection are shown in Figures 7 through 9.

### Stress Plot

9. The normal stress, thrust, bending-stress, and shearing-stress plots for the various sections 1 through 18 and 1A through 10A (Figure 10) are performed using the CSMT computer program and are shown in Appendix A. It is important to note that the actual stress concentration occurs at the various junctions and should be considered in the design analysis.

### Internal Forces

10. The in-house developed computer program CSMT calculated axial and shear forces and bending moments for the various sections in Figure 10 using the graphical stress plots in Appendix A. The axial forces, shear forces, and bending moments at the various sections (Figure 10) due to the simplified frame analysis using beam-column elements and the detailed plane-strain FE analyses were compared for the three load cases and are shown in the Tables 4 through 12. The internal forces agree well except at the member junctions, where heavy stress concentrations occur, and as such adjacent sections (1A through 10A in Figure 10) were investigated, they agree with that of the frame analysis. The graphical plots of bending moments, shear forces, and the axial

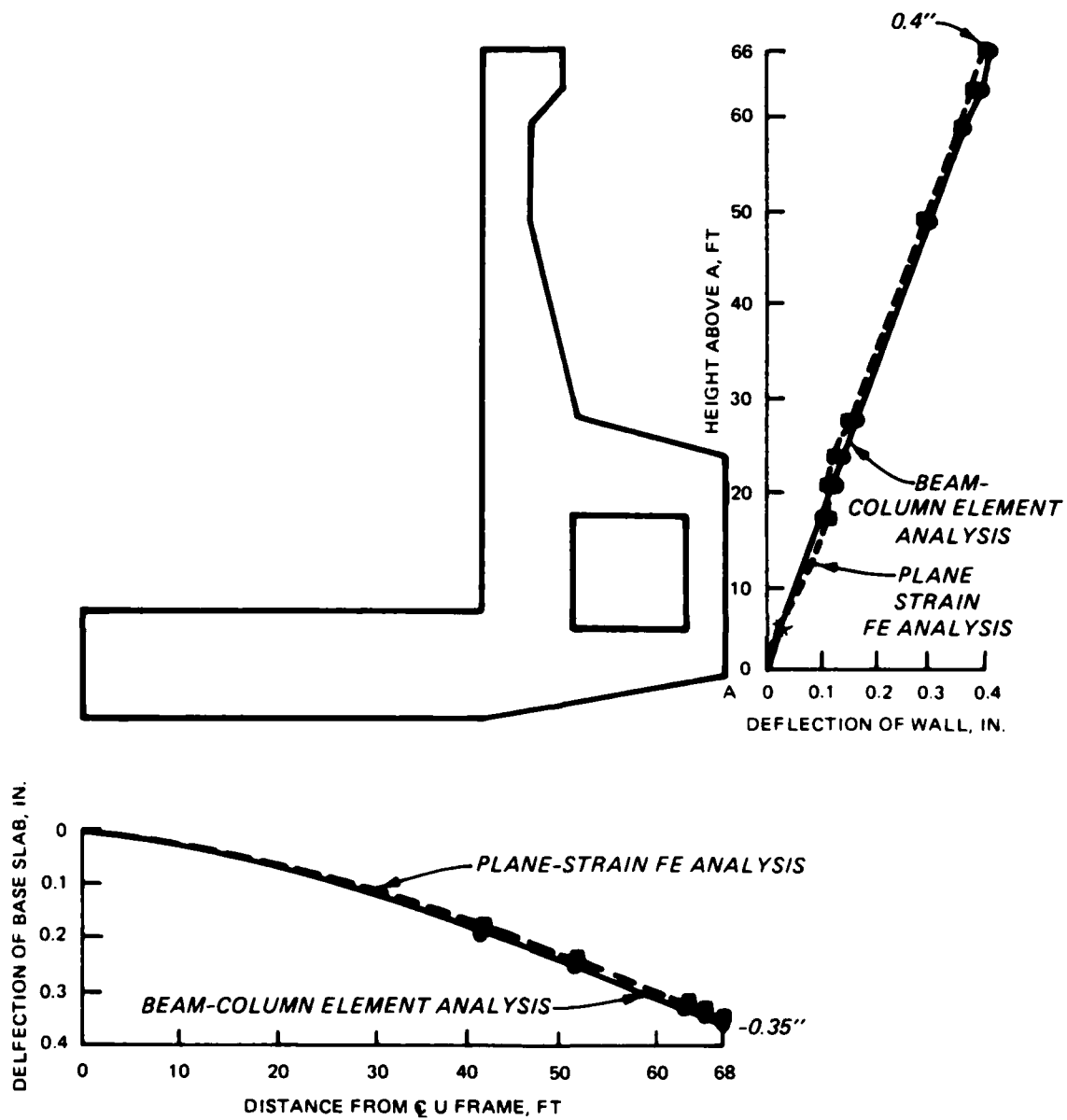


Figure 7. Case 1B--deflection shown in construction with backfill condition

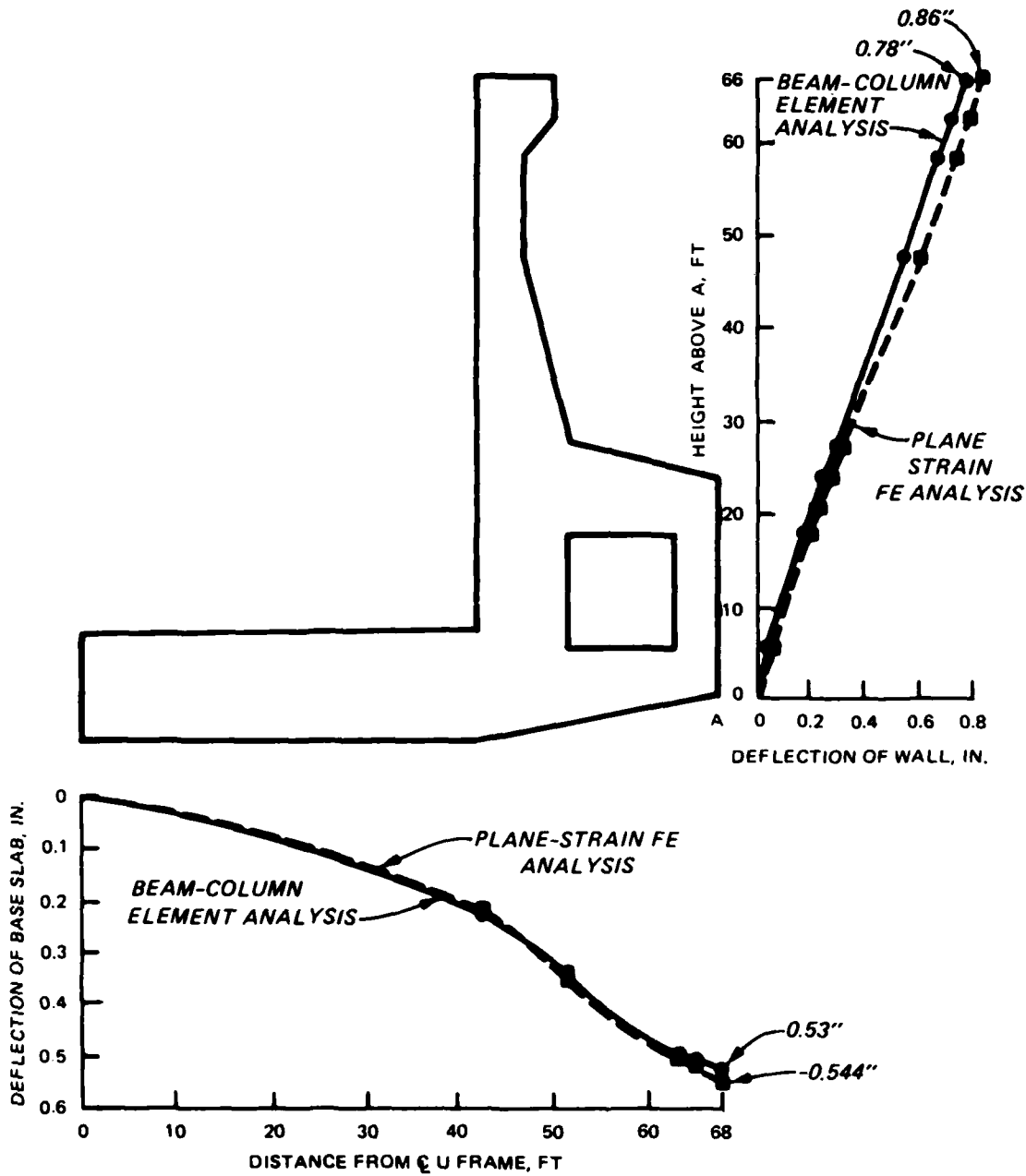


Figure 8. Case 2B--deflection in normal operating condition

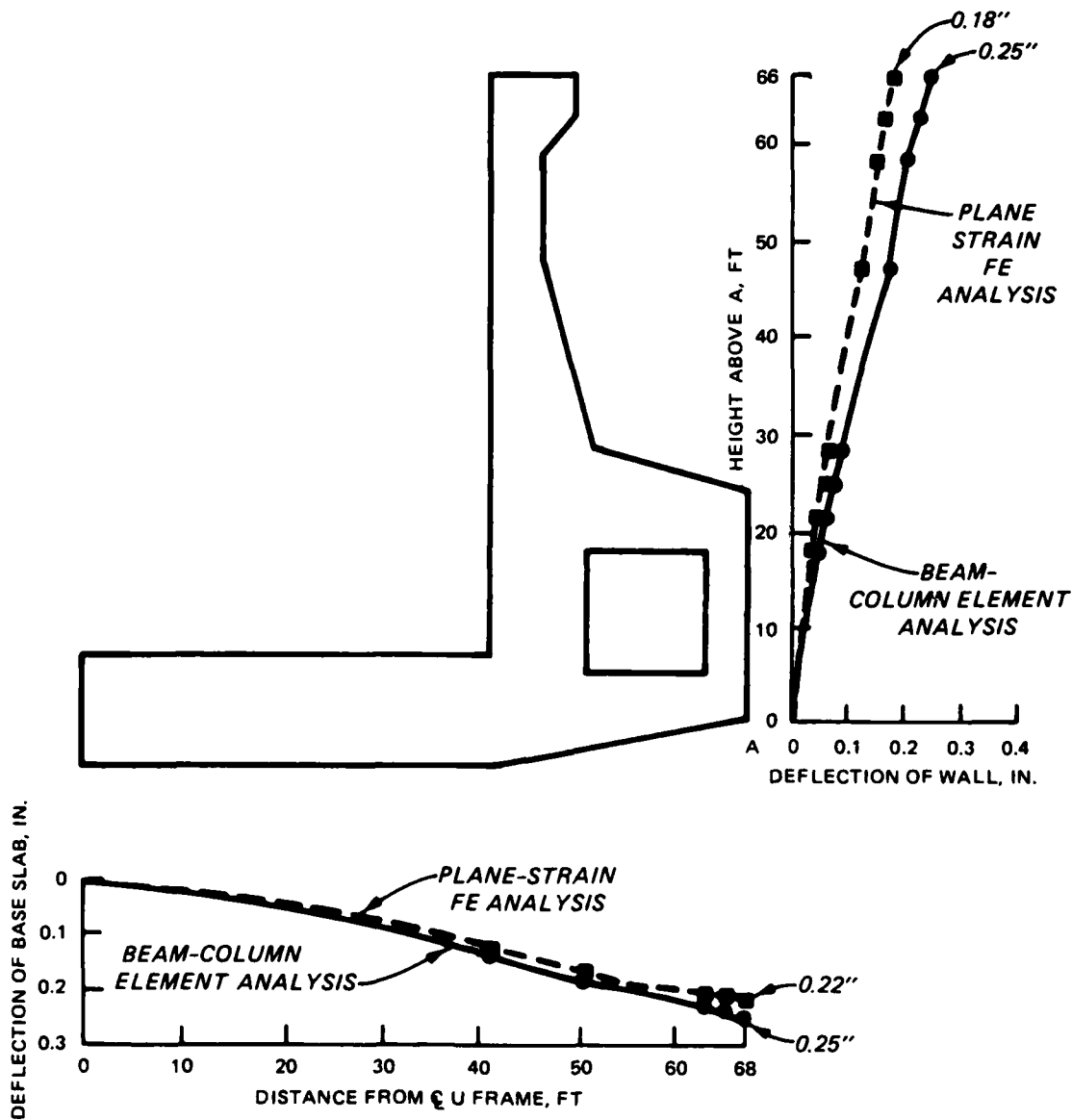


Figure 9. Case 5A--deflection shown in extreme maintenance condition

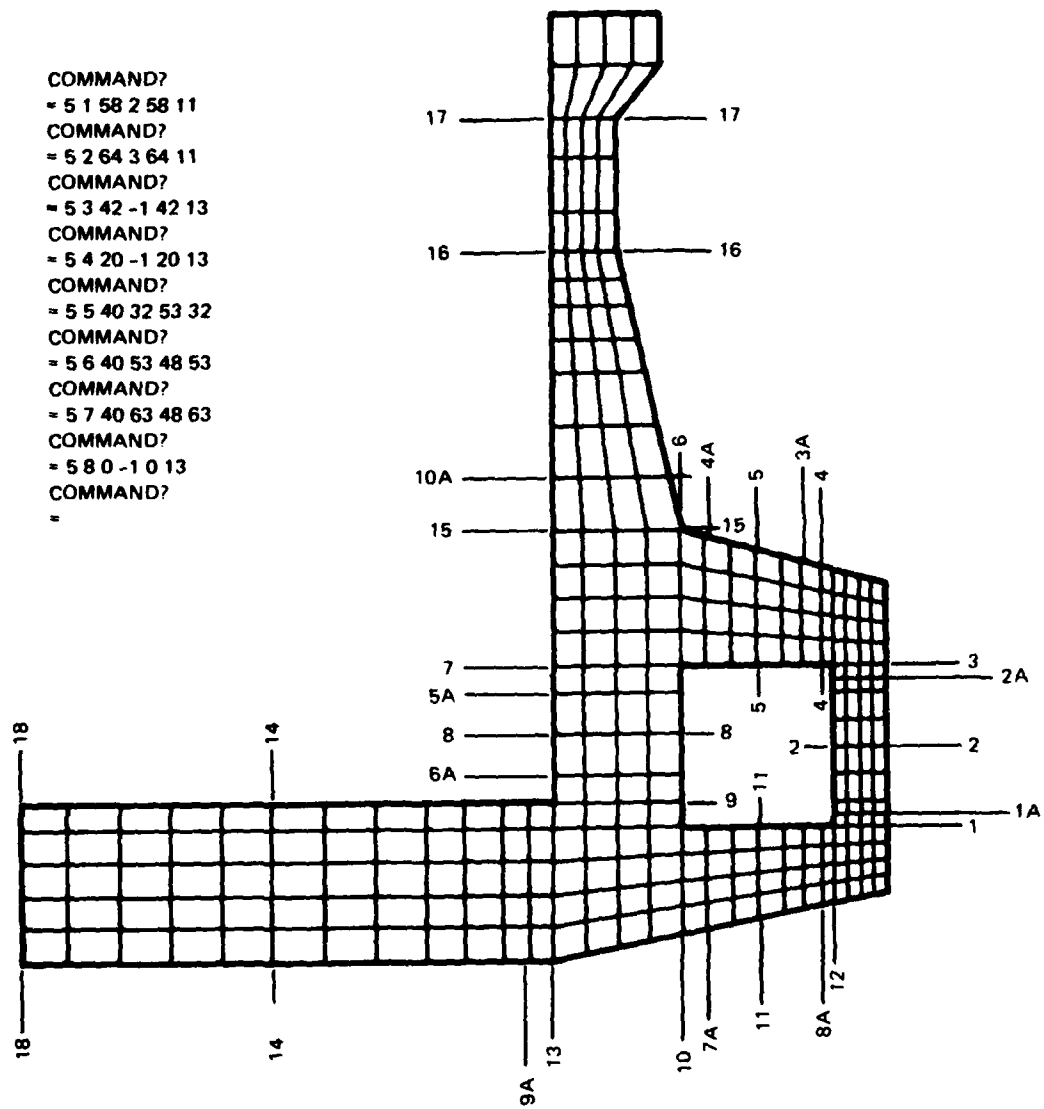


Figure 10. Various sections with FE model

forces for the three different load combinations are shown in Figures 11 through 13. It is to be noted that internal forces at sections 1A through 10A in Figure 10 were taken as the junction internal forces for the plot.

11. During the conduct of this study, Dr. William P. Dawkins completed a preliminary version of the computer program, CUFRAME, for the Computer-Aided Structural Engineering (CASE) project's task group on U-frame structures. CUFRAME uses the same planar rigid-frame analysis that was used for the GTSTRUDL analyses. CUFRAME was designed solely for analysis of U-frame lock structures and requires geometry data, soil data, and water elevation data. CUFRAME discretizes the geometry and uses of the soil and water elevation data to determine the loads on each member. The use of CUFRAME allowed the results shown in Tables 4 through 12 to be calculated in less than one hour as compared to several months for the GTSTRUDL results.



**CONSTRUCTION WITH BACKFILL CONDITION**

— BEAM-COLUMN ELEMENT ANALYSIS  
 - - - PLANE-STRAIN FE ANALYSIS  
 BENDING MOMENT, SHEAR AND AXIAL FORCE IN FT K, K, AND K UNITS.

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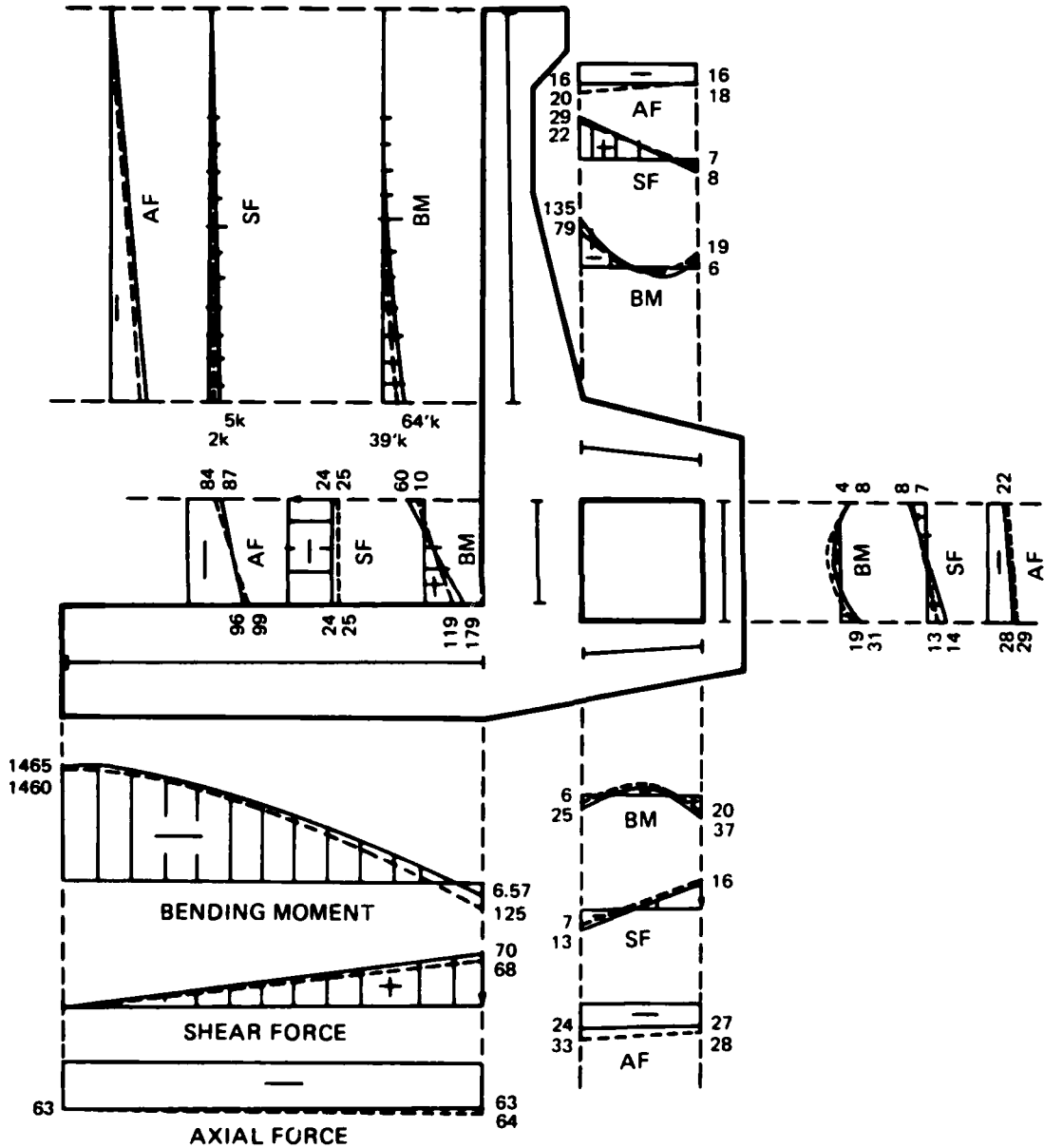


Figure 11. Case 1B--internal forces acting on construction with backfill condition

**NORMAL OPERATING CONDITION**

— BEAM-COLUMN ELEMENT ANALYSIS  
 - - - PLANE-STRAIN FE ANALYSIS  
 BENDING MOMENT, SHEAR AND AXIAL  
 FORCE IN FT K, K, AND K UNITS.

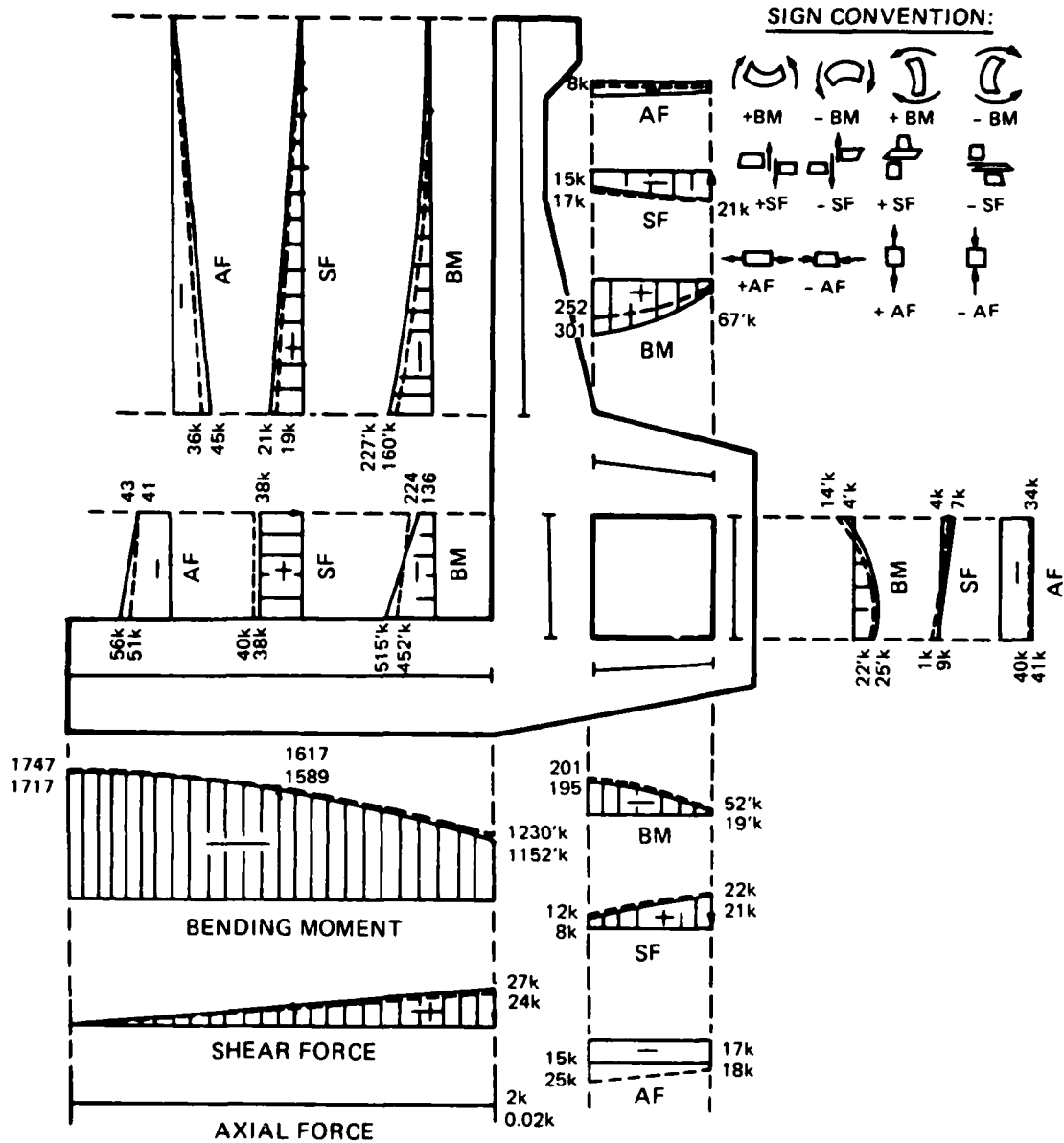


Figure 12. Case 2B--internal forces acting on normal operating condition

**EXTREME MAINTENANCE CONDITION**

— BEAM-COLUMN ELEMENT ANALYSIS  
 - - - PLANE-STRAIN FE ANALYSIS  
 BENDING MOMENT, SHEAR AND AXIAL FORCE IN FT K, K, AND K UNITS.

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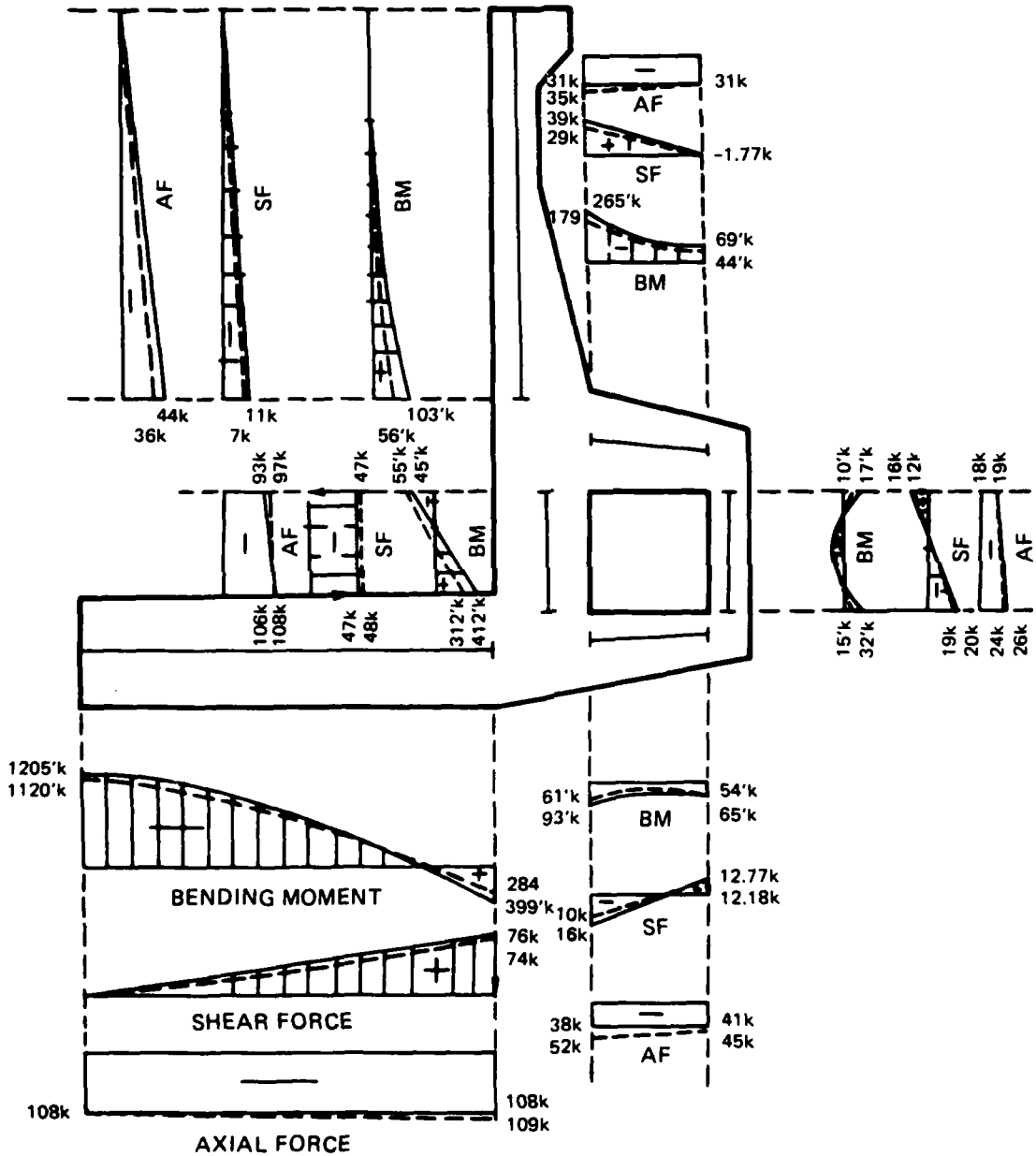


Figure 13. Case 5A--internal forces acting on extreme maintenance condition

### PART III: CONCLUSIONS

12. Comparisons of the structural analysis of the Red River U-frame with a planar frame analysis using beam-column elements and that of detailed plane-strain finite-element model showed the following:

- a. Real soil-structure interaction effects have not been taken into account in either of the model analyses since loads were determined without knowing the final displacements.
- b. In the absence of real soil-structure interaction effects, the linearly elastic overall frame analysis of the U-frame structure agrees reasonably well with that of detailed plane-strain finite-element analysis, except at the juncture points. The displacements of the node points are also in agreement, while internal forces, except right at the juncture points, are similar. Stress concentration exists at the juncture as can be seen from the stress plots of Appendix A and elementary static's and strength of material's formulas may not be used to calculate the internal forces (bending moment, shear force, etc.). However, a little distance away from the juncture, the beam formula can be successfully applied. Therefore, in the absence of soil structure interaction effects, the frame model analysis and design of the overall U-frame structure is adequate except at the juncture, where detailed finite-element analysis is needed.
- c. In finite-element analysis equations of equilibrium are satisfied only in the mean throughout the element and, in general, pointwise equilibrium may not be satisfied within the element or along element juncture lines. It should be anticipated that some difficulties may be confronted in the interpretation of finite-element stress output. The best location for definition of the stress state for design would be at the centroid of each element. One can also calculate the average of the various stress components at the nodes, where a number of elements join. In isoparametric finite-element formulation, the element displacements at any point are directly related with element nodal-point displacements through the use of interpolation functions involving natural coordinates (Gallagher 1975; Bathe and Wilson 1976; Segerlind 1976; and Zeinkiewicz 1971).
- d. In view of the data analysis from the instrumentation program of Port Allen Lock (Sherman and Trahan 1968), Old River Lock (Sherman and Trahan 1972), and that the U-frame walls transfer the heavy load to the ground, the more or less uniform base soil-pressure distribution (Figures 3 through 5) may not be justified.
- e. Errors have been detected in some application of horizontal and vertical pressure loads locally in the frame model U-frame analysis. Pressures could have been applied in the global direction on the projected length of members.

- f. The horizontal soil-pressure diagram (Figure 4) above the water line does not appear to be correct.
- g. It is important that further research study should be extended to the analysis of linearly elastic U-frame structure on elastic foundation (Hetenyi 1971, Timoshenko and Woinowsky-Krieger 1959, Timoshenko and Goodier 1970). A relatively simple and useful computer program could be developed in a reasonable time. This research might be extended into the elasto-plastic (Clough 1969, Pande and Zienkiewicz 1982, and Hoffman and Sachs 1953) foundation study. Dynamic soil-structure interaction effects due to seismic loading may also be included in future investigations.

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Table 1

Case 1B--Deflection in Construction with Backfill, Without Earthquake

Frame Model Joint	FEM		Frame	
	X Displacement in.	Y Displacement in.	X Displacement in.	Y Displacement in.
1	0.00	0.00	0.0	0.0
2	-0.0029271	-0.1765026	-0.00523	-0.17746
3			-0.00591	-0.21118
4	-0.0052825	-0.241266	-0.00642	-0.24483
5	0.0010996	-0.3188311	0.00002	-0.32570
6	0.0022717	-0.3316765	0.00107	-0.33909
7	0.0034090	-0.3443291	0.00236	-0.35243
8	0.0191137	-0.3319080	0.01895	-0.33955
9	0.097427	-0.3334830	0.09796	-0.34136
10	0.1136865	-0.3337401	0.11984	-0.34178
11	0.1120579	-0.3465438	0.11816	-0.35520
12	0.1153249	-0.3209987	0.12164	-0.32838
13	0.1253805	-0.2439175	0.13220	-0.24852
14	0.0208578	-0.2098095	0.02095	-0.21215
15	0.0334889	-0.2101092	0.03434	-0.21263
16	0.0944080	-0.2119734	0.09980	-0.21481
17	0.1253082	-0.2126774	0.13243	-0.21576
18	0.1562741	-0.2133097	0.16508	-0.21631
19	0.2828945	-0.1999945	0.30040	-0.20201
20	0.3449428	-0.2005635	0.36609	-0.20262
21	0.3704964	-0.2118484	0.39294	-0.21448
22	0.3960874	-0.2118926	0.41985	-0.21451
23	-0.0149750	-0.3314818	-0.016404	-0.337848
24	0.1345276	-0.3339089	0.135888	-0.340536

Table 2

Case 2B--Deflection in Normal Operating, with Upper Pool

Frame Model Joint	FEM		Frame	
	X Displacement in.	Y Displacement in.	X Displacement in.	Y Displacement in.
1	0.0	0.0	0.0	0.0
2	0.0031655	-0.2329987	-0.00013	-0.23631
3			-0.00014	-0.28960
4	-0.0001865	-0.3455102	-0.00058	-0.34330
5	0.0132501	-0.4927854	0.01148	-0.48038
6	0.0156973	-0.5185946	0.01363	-0.50425
7	0.0181065	-0.5442583	0.01592	-0.52808
8	0.0501277	-0.5191073	0.04569	-0.50491
9	0.1955552	-0.5214308	0.18128	-0.50757
10	0.2333041	-0.5219483	0.21690	-0.50822
11	0.2303994	-0.5451386	0.21416	-0.53017
12	0.2361967	-0.4988702	0.21969	-0.48628
13	0.2543915	-0.3550763	0.23688	-0.35069
14	0.0439854	-0.2893636	0.04286	-0.29017
15	0.0667432	-0.2899749	0.06447	-0.29044
16	0.1906278	-0.2911323	0.17819	-0.29160
17	0.2542107	-0.2916415	0.23695	-0.29205
18	0.3182292	-0.2919328	0.29584	-0.29260
19	0.6038447	-0.2596522	0.55297	-0.26329
20	0.7462003	-0.2602082	0.68016	-0.26451
21	0.8038702	-0.2855444	0.73165	-0.28715
22	0.8615776	-0.2855885	0.78320	-0.28718
23	-0.0187361	-0.5182546	-0.016668	-0.503640
24	0.2712500	-0.5221949	0.244680	-0.507612



Table 3

Case 5A--Deflection in Extreme Maintenance

Frame Model Joint	FEM		Frame	
	X Displacement in.	Y Displacement in.	X Displacement in.	Y Displacement in.
1	0.0	0.0	0.0	0.0
2	-0.0068868	-0.1284984	-0.00394	-0.13630
3			-0.01011	-0.15935
4	-0.0090617	-0.1663310	-0.01091	-0.18219
5	-0.0068066	-0.2075054	-0.00773	-0.23422
6	-0.0063740	-0.2136300	-0.00731	-0.24231
7	-0.0059710	-0.2195485	-0.00653	-0.25033
8	0.0013590	-0.2137364	0.00338	-0.24272
9	0.0380905	-0.2149872	0.05379	-0.24432
10	0.0501485	-0.2151258	0.06857	-0.24468
11	0.0491539	-0.2224290	0.06744	-0.25370
12	0.0511549	-0.2078797	0.06991	-0.23571
13	0.0571094	-0.1663269	0.07738	-0.18435
14	0.0069197	-0.1484623	0.00805	-0.16041
15	0.0139670	-0.1486287	0.01703	-0.16093
16	0.0426947	-0.1505764	0.05804	-0.16332
17	0.0571434	-0.1512803	0.07780	-0.16438
18	0.0717463	-0.1519859	0.09758	-0.16494
19	0.1280442	-0.1470509	0.17810	-0.15717
20	0.1566077	-0.1476200	0.21769	-0.15778
21	0.1687674	-0.1530450	0.23409	-0.16508
22	0.1809646	-0.1530892	0.25056	-0.16511
23	-0.0147080	-0.2134902	-0.019908	-0.241788
24	0.0619024	-0.2152614	0.077280	-0.244140

Table 4

Case 1B--Construction Condition, Axial Force, kips

<u>Section</u>	<u>Frame</u>	<u>Plane Strain</u>	<u>Section</u>	<u>Plane Strain</u>	<u>CUFRAM</u>
1	28.96	30.17	1A	28.17	28.43
2	-25.36	-25.01			
3	-21.76	-22.25	2A	-22.09	-21.23
4	-17.74	-17.68	3A	-16.39	-16.30
5	-16.88	-17.84			
6	15.83	26.68	4A	19.80	14.41
7	-84.13	-89.87	5A	-87.28	-84.59
8	-91.62	-93.46			
9	99.12	105.97	6A	96.11	99.59
10	24.36	39.18	7A	33.34	33.71
11	-25.71	-31.00			
12	-27.06	-31.99	8A	-28.44	-30.39
13	-62.92	-80.74	9A	-64.37	-62.92
14	-62.92	-62.88			
15	-42.56	-43.56	10A	-35.37	-41.65
16	-16.56	-16.68			-16.53
17	-9.18	-9.88			9.15
18	62.92	62.88			62.92

Table 5

Case 1B--Construction Condition, Shear Force, kips

<u>Section</u>	<u>Frame</u>	<u>Plane Strain</u>	<u>Section</u>	<u>Plane Strain</u>	<u>CUFRAM</u>
1	-13.61	-14.52	1A	-12.64	-14.98
2	1.5200	2.22			
3	-8.23	-8.31	2A	-6.57	-6.86
4	7.65	10.85	3A	6.64	7.30
5	-10.48	-8.88			
6	28.75	31.75	4A	21.93	29.10
7	23.96	29.79	5A	24.60	22.59
8	23.96	24.45			
9	-23.96	-32.67	6A	-24.85	-22.59
10	-13.16	-14.27	7A	-7.10	-14.67
11	-0.9163	-2.78			
12	-15.88	-22.67	8A	-16.01	-14.95
13	-70.14	-78.05	9A	-68.37	-70.09
14	-33.3744	-34.69			
15	4.68	3.41	10A	2.28	9.67
16	-1.97	-0.0864			-1.97
17	-0.0000	-0.53			0.0
18	-0.0456	-0.0099			0.0

Table 6

Case 1B--Construction Condition, Moment,  $M_z$ , kip-feet

<u>Section</u>	<u>Frame</u>	<u>Plane Strain</u>	<u>Section</u>	<u>Plane Strain</u>	<u>CUFRAM</u>
1	-30.82	-3.37	1A	-18.76	-41.19
2	-14.5700	-15.58			
3	7.93	16.56	2A	4.06	1.77
4	-18.97	-0.2448	3A	-5.98	-9.06
5	-17.14	-17.35			
6	134.83	130.72	4A	79.16	129.1
7	-60.14	-2.89	5A	-10.34	-63.44
8	59.69	56.87			
9	-179.49	-91.74	6A	-118.54	-162.4
10	-25.19	-17.52	7A	-6.13	-20.82
11	-11.9604	-18.66			
12	37.48	31.20	8A	19.70	39.63
13	6.57	84.53	9A	125.38	8.86
14	-1132.05	-1129.54			
15	64.32	58.95	10A	38.85	64.80
16	12.50	12.63			12.78
17	-12.50	-12.28			-12.77
18	1465.34	1460.16			1473.00

Table 7

Case 2B--Normal Operation, Axial Force, kips

<u>Section</u>	<u>Frame</u>	<u>Plane Strain</u>	<u>Section</u>	<u>Plane Strain</u>	<u>CUFRAM</u>
1	40.9782	47.3328	1A	40.0320	39.22
2	-37.3782	-37.4112			
3	-33.7782	-39.0816	2A	-34.0272	-32.02
4	-6.2815	-9.7920	3A	-5.8464	-6.758
5	-6.1133	-5.4864			
6	8.0583	4.8816	4A	6.9696	8.814
7	-41.2954	-42.3504	5A	-42.8688	-43.06
8	-48.7954	-46.0512			
9	56.2954	40.4208	6A	50.7168	58.06
10	15.6427	12.4560	7A	25.4880	25.32
11	-16.2461	-20.4480			
12	-16.8495	-21.4992	8A	-17.7120	-18.38
13	-1.5395	-60.5232	9A	-0.3456	-2.361
14	-1.5395	-0.0432			
15	44.7414	37.8576	10A	35.6544	45.20
16	-16.9027	-16.6464			-16.90
17	-9.1500	-9.8784			-9.150
18	1.5395	0.0288			2.361

Table 8

Case 2B--Normal Operation, Shear Force, kips

<u>Section</u>	<u>Frame</u>	<u>Plane Strain</u>	<u>Section</u>	<u>Plane Strain</u>	<u>CUFRAM</u>
1	0.8917	1.9584	1A	1.3824	1.873
2	2.2058	0.7344			
3	6.5183	5.8032	2A	4.0320	5.536
4	21.2028	21.5856	3A	21.4992	19.37
5	-18.3828	-19.0368			
6	-15.3270	-15.3216	4A	-17.4672	-13.46
7	-37.8563	-38.5488	5A	-38.6496	-40.77
8	-37.8563	-39.1968			
9	37.8563	58.3200	6A	40.4064	40.77
10	8.3919	15.2496	7A	11.9808	5.581
11	-14.6088	-16.0992			
12	-21.3755	-24.0192	8A	-22.0032	-19.39
13	-26.9587	-1.5984	9A	-23.8176	-26.86
14	-12.8259	-13.4064			
15	21.4513	16.2864	10A	19.2240	20.15
16	1.1348	3.2400			1.135
17	0.0000	0.5184			0.0
18	-0.0221	-0.0720			0.0

Table 9

Case 2B--Normal Operation, Moment,  $M_z$ , kip-feet

<u>Section</u>	<u>Frame</u>	<u>Plane Strain</u>	<u>Section</u>	<u>Plane Strain</u>	<u>CUFRAM</u>
1	-24.5916	-5.6736	1A	-22.3344	-20.12
2	20.0418	25.7904			
3	-4.3079	-11.8656	2A	-13.7088	-3.008
4	66.3829	34.9056	3A	67.2048	53.76
5	394.7964	170.6400			
6	-301.4196	-224.9280	4A	-231.8400	-264.5
7	-136.0537	-116.2368	5A	-223.6320	-234.2
8	-325.3350	-347.4720			
9	514.6165	624.0960	6A	451.7280	641.9
10	195.4966	291.6000	7A	201.0240	216.7
11	-126.4857	-149.7600			
12	-18.5451	-24.3648	8A	-52.0128	-39.99
13	-1151.5437	-1568.1600	9A	-1230.0480	-1281.0
14	-1589.1734	-1617.1200			
15	-227.1848	-204.4800	10A	-160.1280	-245.5
16	22.8689	22.7664			23.19
17	-12.4522	-12.2400			-12.77
18	1717.2117	1746.7200			1845.0

Table 10

Case 5A--Extreme Maintenance, Axial Force, kips

<u>Section</u>	<u>Frame</u>	<u>Plane Strain</u>	<u>Section</u>	<u>Plane Strain</u>	<u>CUFRAM</u>
1	25.99	26.57	1A	24.39	26.07
2	-22.39	-20.97			
3	-18.79	-18.38	2A	-18.26	-18.87
4	-30.71	-31.68	3A	-28.97	-28.05
5	-30.52	-32.21			
6	30.52	45.65	4A	34.79	27.87
7	-93.12	-101.51	5A	-96.57	-93.03
8	-100.62	-103.64			
9	108.12	124.76	6A	105.85	108.0
10	38.20	65.39	7A	51.74	53.81
11	-40.86	-49.02			
12	-40.86	-48.99	8A	-44.57	-46.79
13	-107.63	-153.50	9A	-109.31	-107.7
14	-107.63	-107.65			
15	-43.58	-45.86	10A	-36.07	-41.92
16	-16.56	-16.68			-16.53
17	-9.18	-9.88			-9.15
18	107.63	107.65			107.7



Table 11

Case 5A--Extreme Maintenance, Shear Force, kips

<u>Section</u>	<u>Frame</u>	<u>Plane Strain</u>	<u>Section</u>	<u>Plane Strain</u>	<u>CUFRAM</u>
1	-20.43	-22.56	1A	-19.28	-23.18
2	0.65	2.28			
3	-15.66	-15.74	2A	-12.23	-12.91
4	1.77	6.80	3A	1.54	2.202
5	-18.58	-15.02			
6	38.63	41.39	4A	29.38	38.20
7	46.54	53.63	5A	47.03	43.85
8	46.54	47.02			
9	-46.54	-64.02	6A	-47.85	-43.85
10	-16.34	-19.83	7A	-10.11	-17.89
11	2.47	0.17			
12	-12.18	-20.69	8A	-12.77	-11.56
13	-76.38	-94.32	9A	-74.13	-76.35
14	-36.37	-36.48			
15	-11.46	-9.04	10A	-6.82	-16.53
16	-1.97	-0.09			-1.968
17	-0.00	-0.53			0.0
18	-0.00001	-1.27			0.0

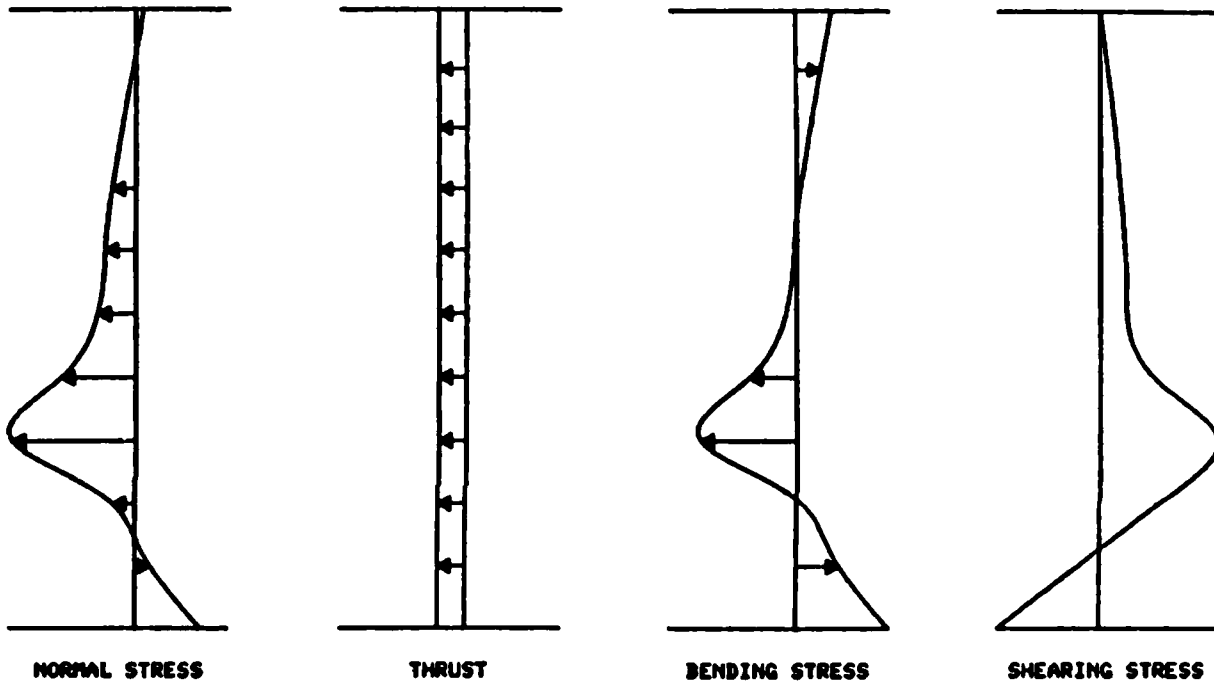
Table 12

Case 5A--Extreme Maintenance, Moment,  $M_z$ , kip-feet

<u>Section</u>	<u>Frame</u>	<u>Plane Strain</u>	<u>Section</u>	<u>Plane Strain</u>	<u>CUFRAM</u>
1	-31.55	-9.72	1A	-14.82	-51.66
2	-29.965	-35.87			
3	16.84	12.90	2A	9.98	3.848
4	-69.09	-23.56	3A	-44.02	-40.42
5	-91.04	-90.43			
6	264.99	234.72	4A	178.56	237.0
7	-44.50	-21.28	5A	-55.34	-29.21
8	188.21	190.51			
9	-420.91	-351.94	6A	-312.48	-409.3
10	-92.50	-109.86	7A	-60.97	-78.27
11	36.69	36.36			
12	65.10	55.53	8A	53.94	71.75
13	399.43	658.66	9A	283.96	388.3
14	-840.80	-783.94			
15	103.19	91.58	10A	56.30	103.5
16	12.50	12.63			-12.78
17	-12.50	-12.28			-12.78
18	1204.65	1120.18			-1215.0

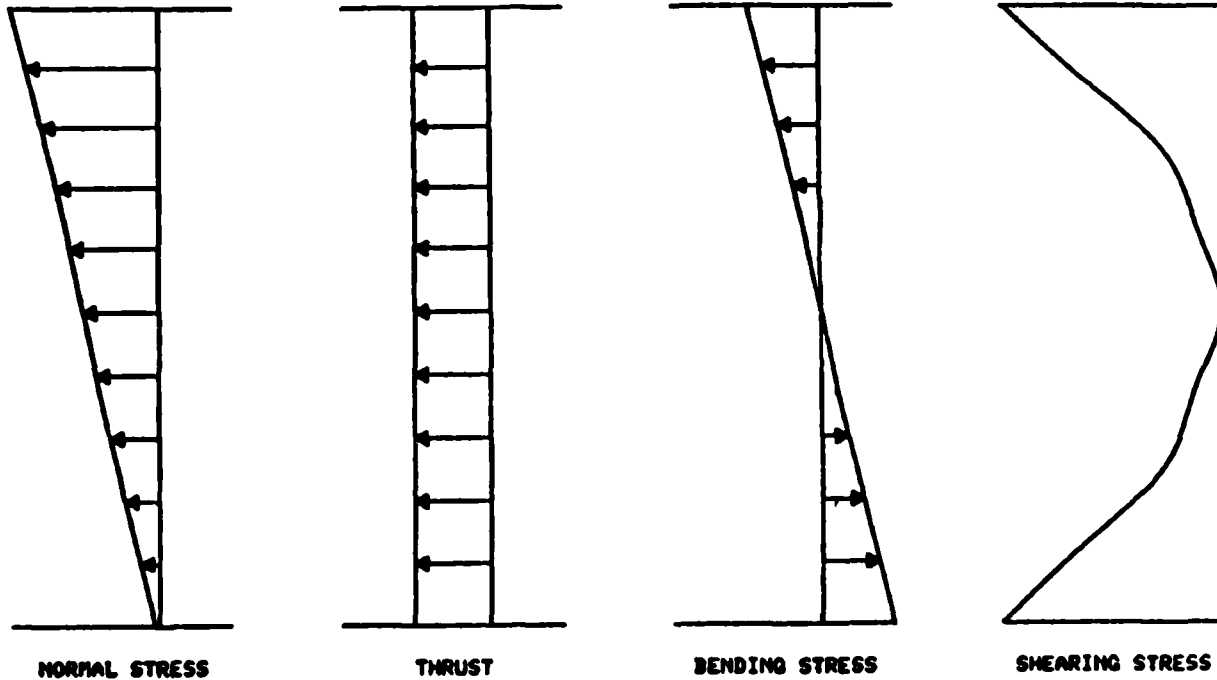
APPENDIX A: STRESS-PLOT AND INTERNAL-FORCES CALCULATION  
FOR VARIOUS SECTIONS OF THREE LOAD COMBINATIONS

NOTE: THE INTERNAL FORCES AND MOMENTS ARE TO BE MULTIPLIED  
BY 144 TO GET INTO KIPS AND KIP-FT UNITS



(X1, Y1) • (62.,10.)  
 (X2, Y2) • (70.,10.)  
 NEUTRAL AXIS • (66.03,10.)  
 SHEAR • .1008  
 MOMENT • -.0234  
 THRUST • -.2095

Figure A1. Load case 1B (section 1)



**NORMAL STRESS**

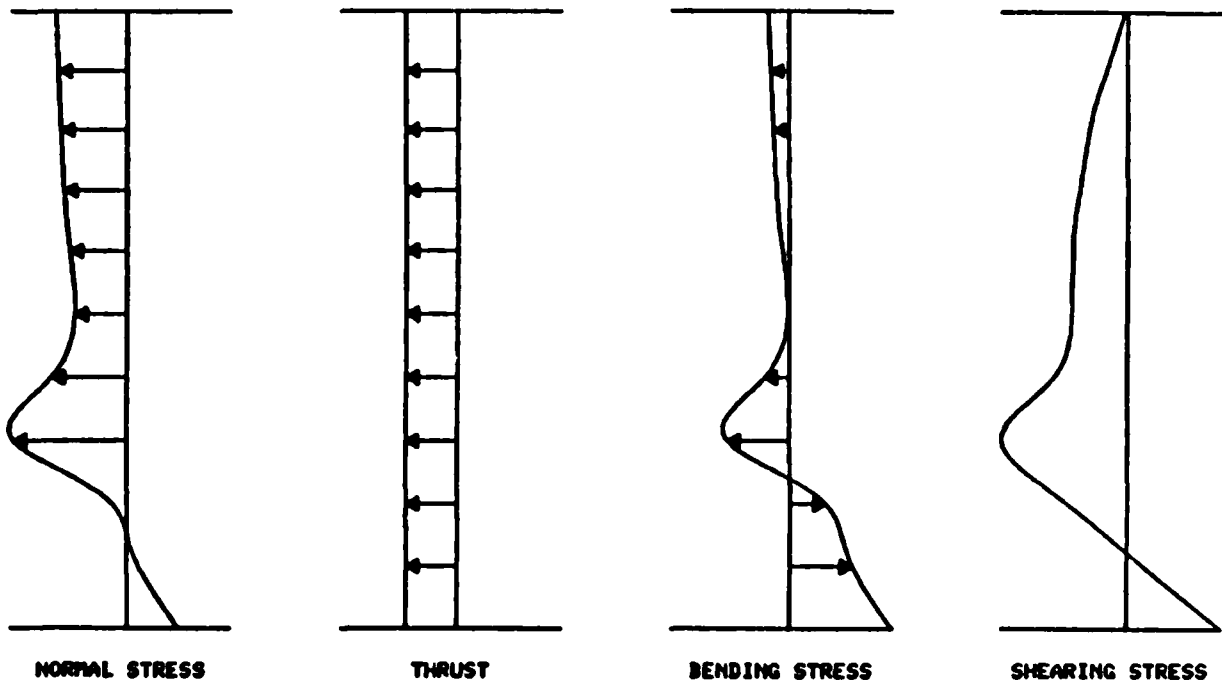
**THRUST**

**BENDING STRESS**

**SHEARING STRESS**

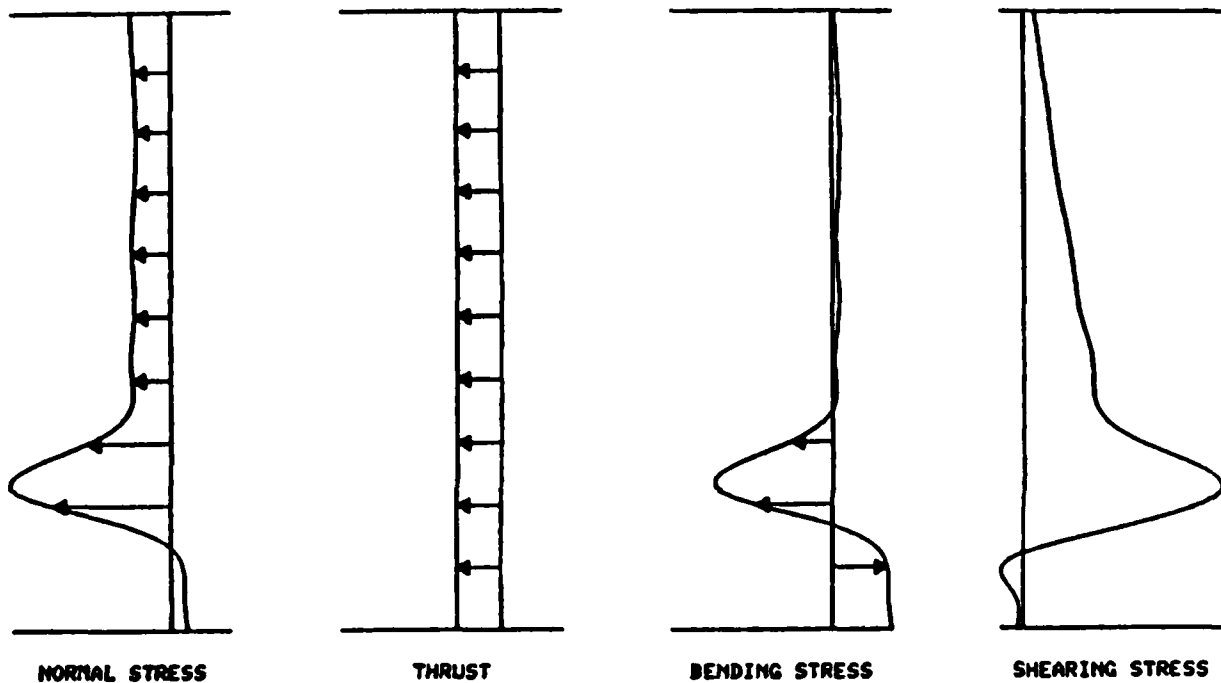
(X1, Y1) = (62., 16.)  
 (X2, Y2) = (70., 16.)  
 NEUTRAL AXIS = (66., 16.)  
 SHEAR = .0154  
 MOMENT = .1082  
 THRUST = -.1737

Figure A2. Load case 1B (section 2)



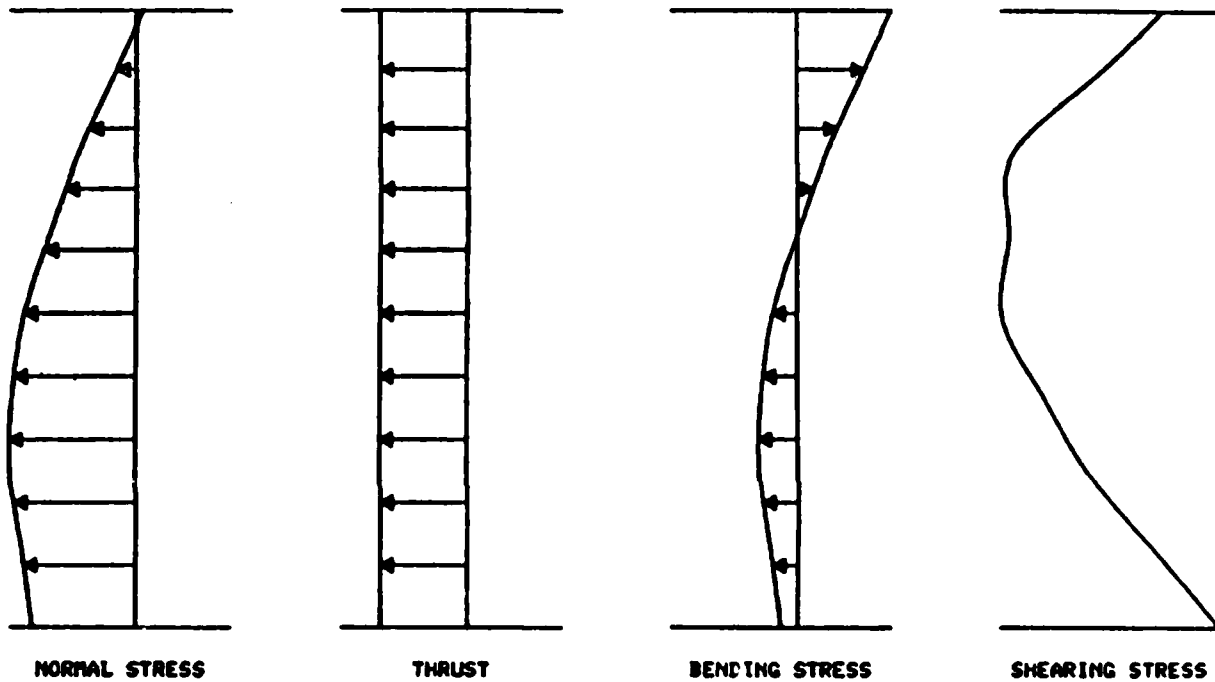
(X1, Y1) • (62.,22.)  
 (X2, Y2) • (76.,22.)  
 NEUTRAL AXIS • (63.63,22.)  
 SHEAR • -.0577  
 MOMENT • .115  
 THRUST • -.1546

Figure A3. Load case 1B (section 3)



(X1, Y1) = (64., 20.)  
 (X2, Y2) = (64., 30.)  
 NEUTRAL AXIS = (64., 23.68)  
 SHEAR = .0754  
 MOMENT = -.0017  
 THRUST = -.1228

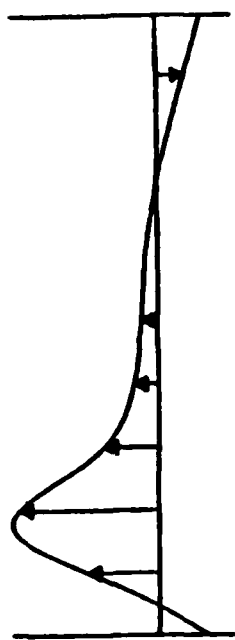
Figure A4. Load case 1B (section 4)



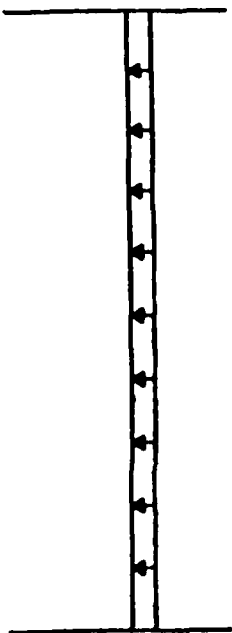
(X1, Y1) • (58., 20.)  
 (X2, Y2) • (58., 32.)  
 NEUTRAL AXIS • (58., 27.29)  
 SHEAR • -.0617  
 MOMENT • -.1205  
 THRUST • -.1239

Figure A5. Load case 1B (section 5)





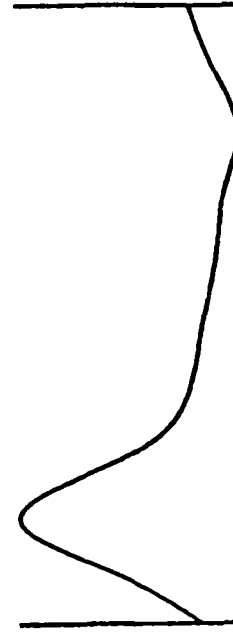
**NORMAL STRESS**



**THRUST**



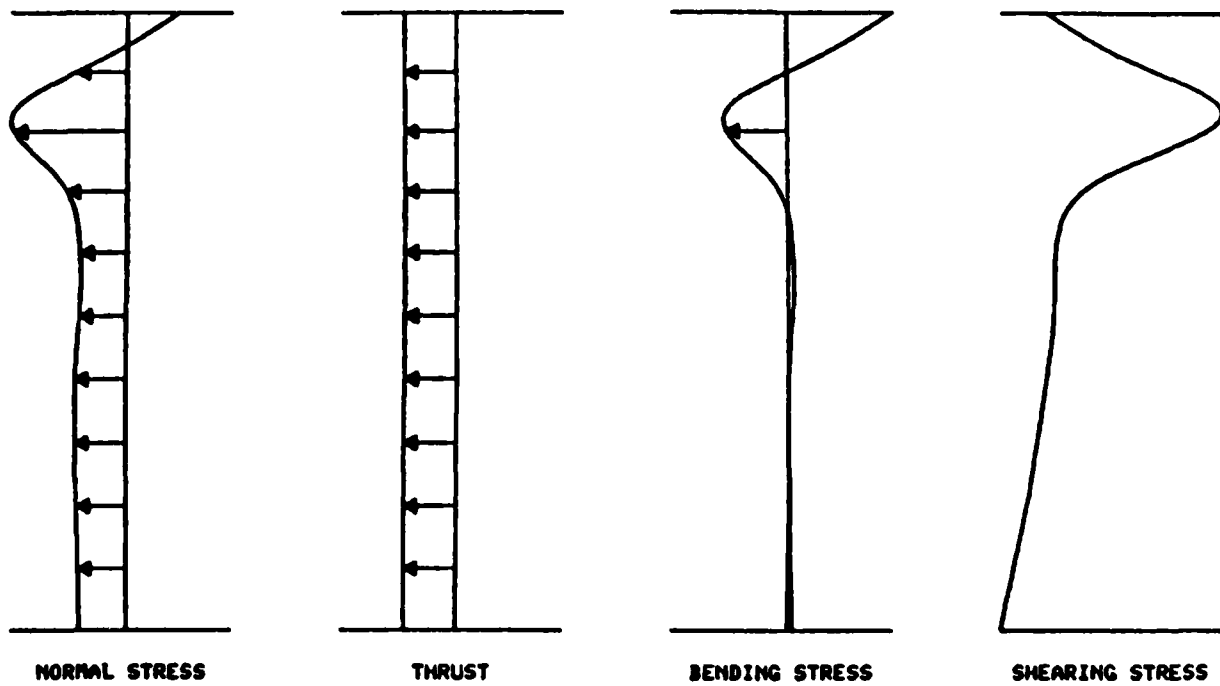
**BENDING STRESS**



**SHEARING STRESS**

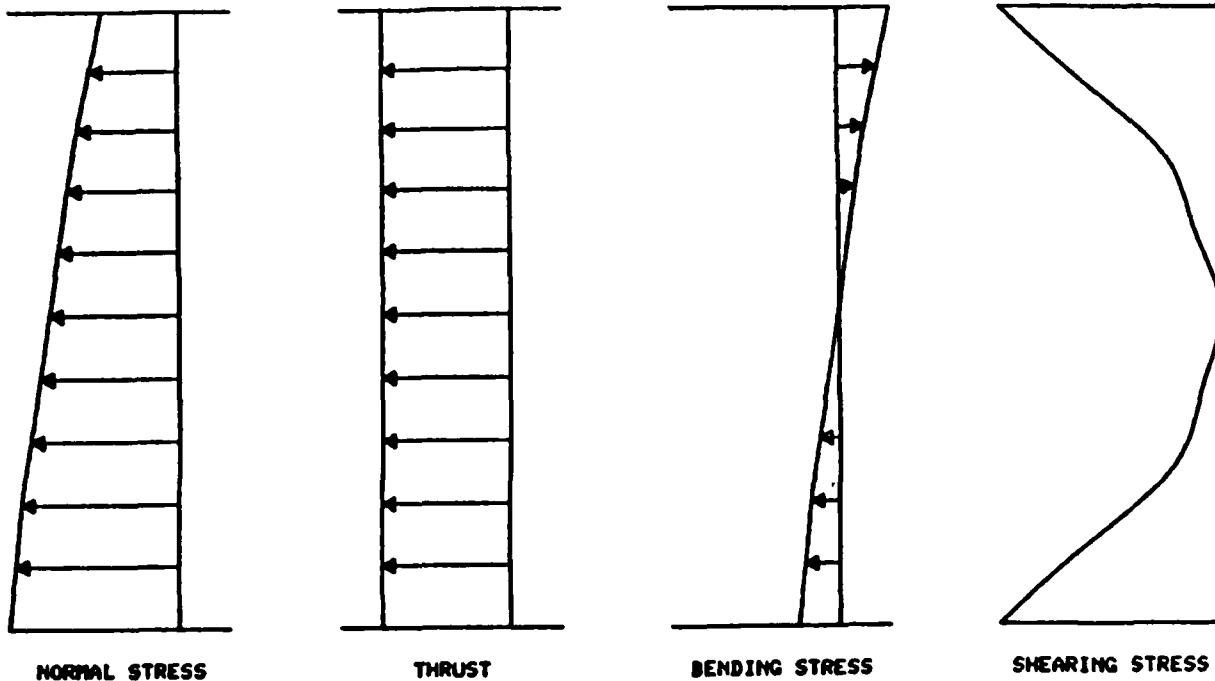
(X1, Y1) = (52.,20.)  
 (X2, Y2) = (52.,33.)  
 NEUTRAL AXIS = (52.,25.03)  
 SHEAR = -.2205  
 MOMENT = -.9078  
 THRUST = -.1853

Figure A6. Load case 1B (section 6)



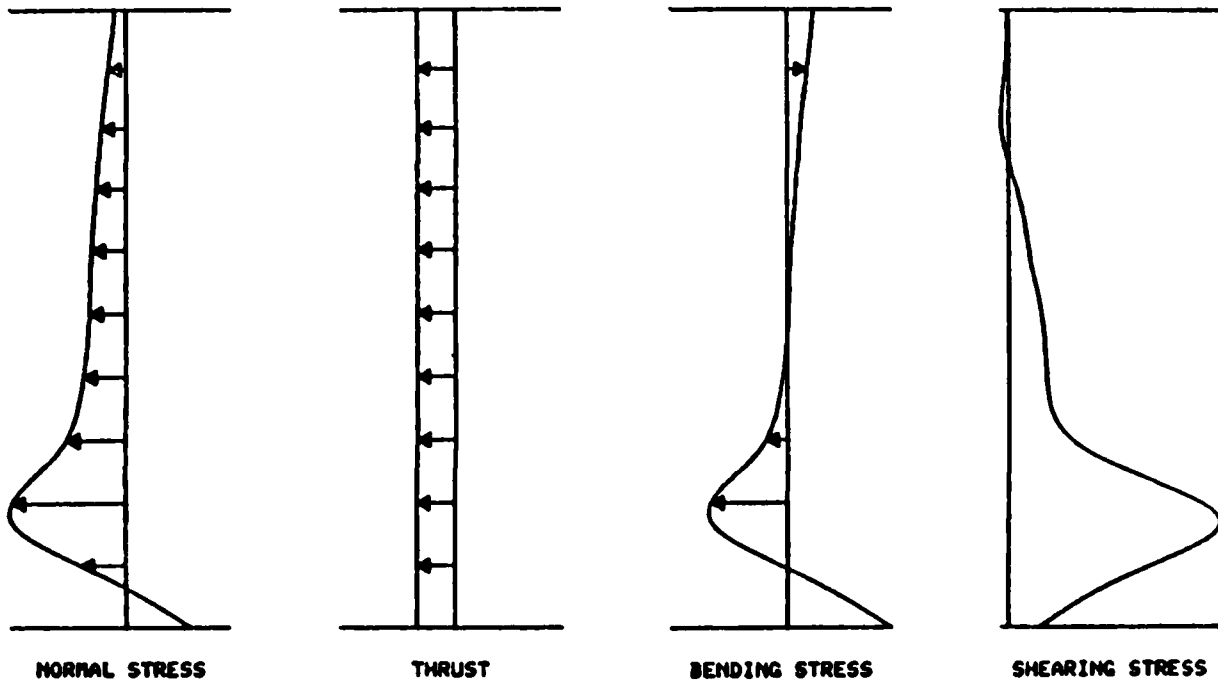
(X1, Y1) = (40., 22.)  
 (X2, Y2) = (54., 22.)  
 NEUTRAL AXIS = (52.74, 22.)  
 SHEAR = .2069  
 MOMENT = -.0201  
 THRUST = -.6241

Figure A7. Load case 1B (section 7)



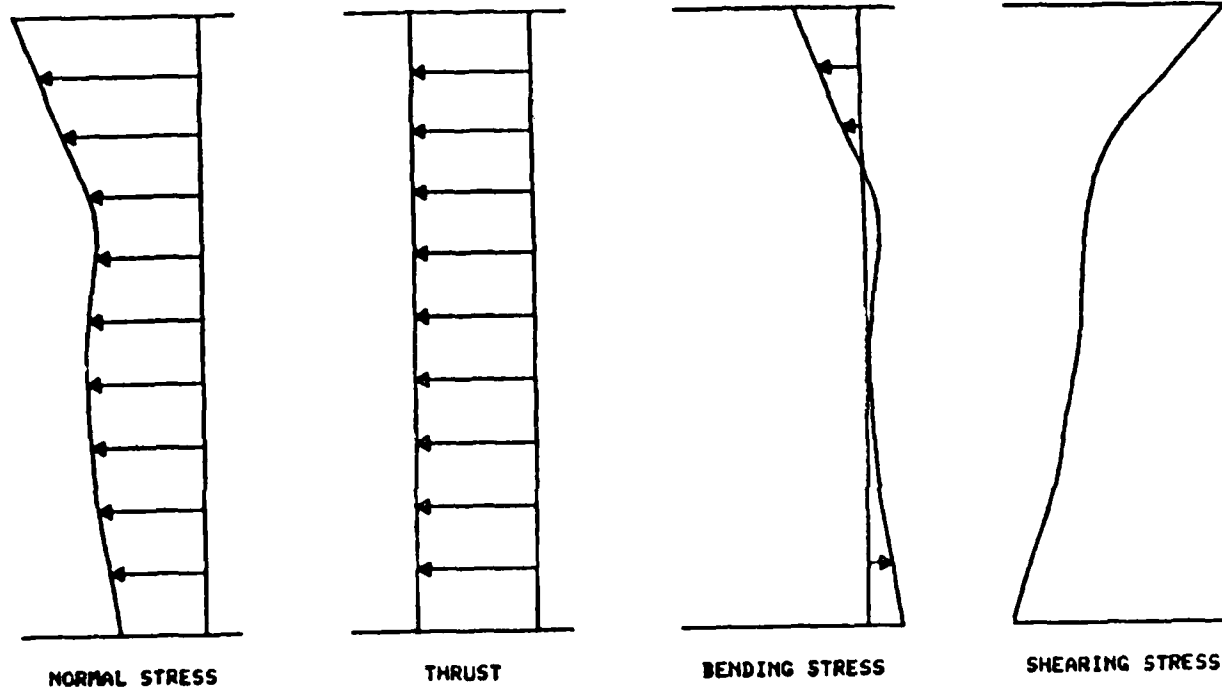
(X1, Y1) = (40., 17.)  
 (X2, Y2) = (54., 17.)  
 NEUTRAL AXIS = (47.14, 17.)  
 SHEAR = .1698  
 MOMENT = -.3949  
 THRUST = -.649

Figure A8. Load case 1B (section 8)



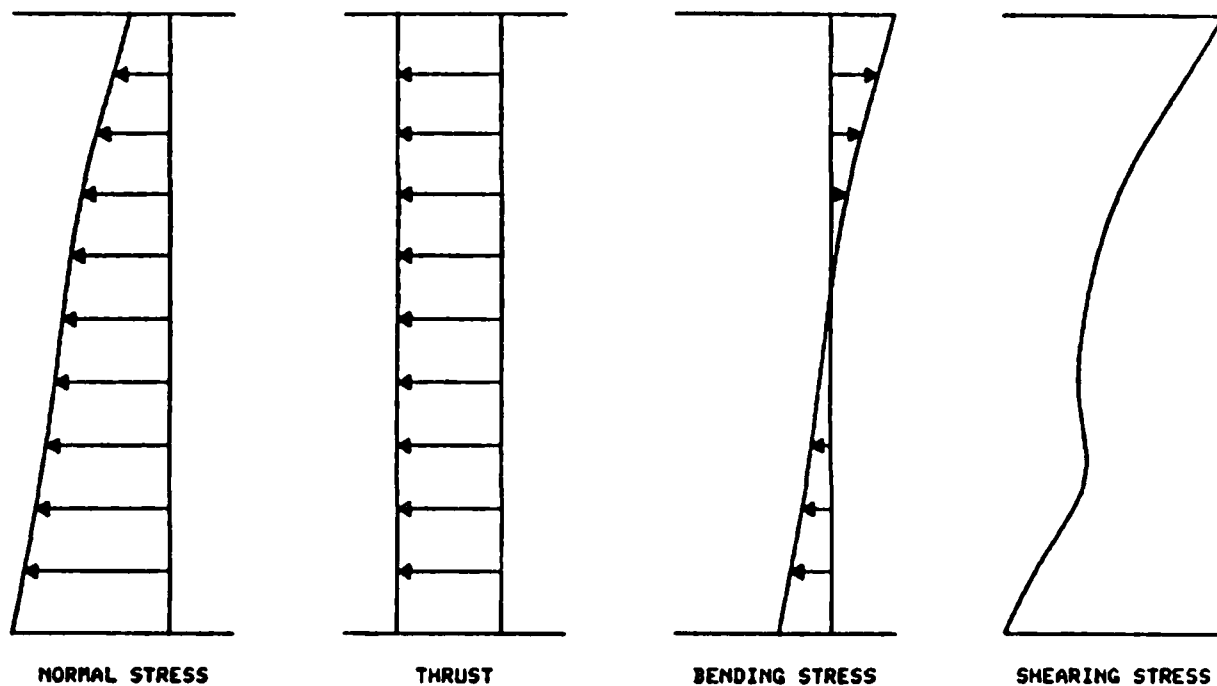
(X1, Y1) = (40., 12.)  
 (X2, Y2) = (54., 12.)  
 NEUTRAL AXIS = (45.64, 12.)  
 SHEAR = .2269  
 MOMENT = -.6371  
 THRUST = -.7359

Figure A9. Load case 1B (section 9)



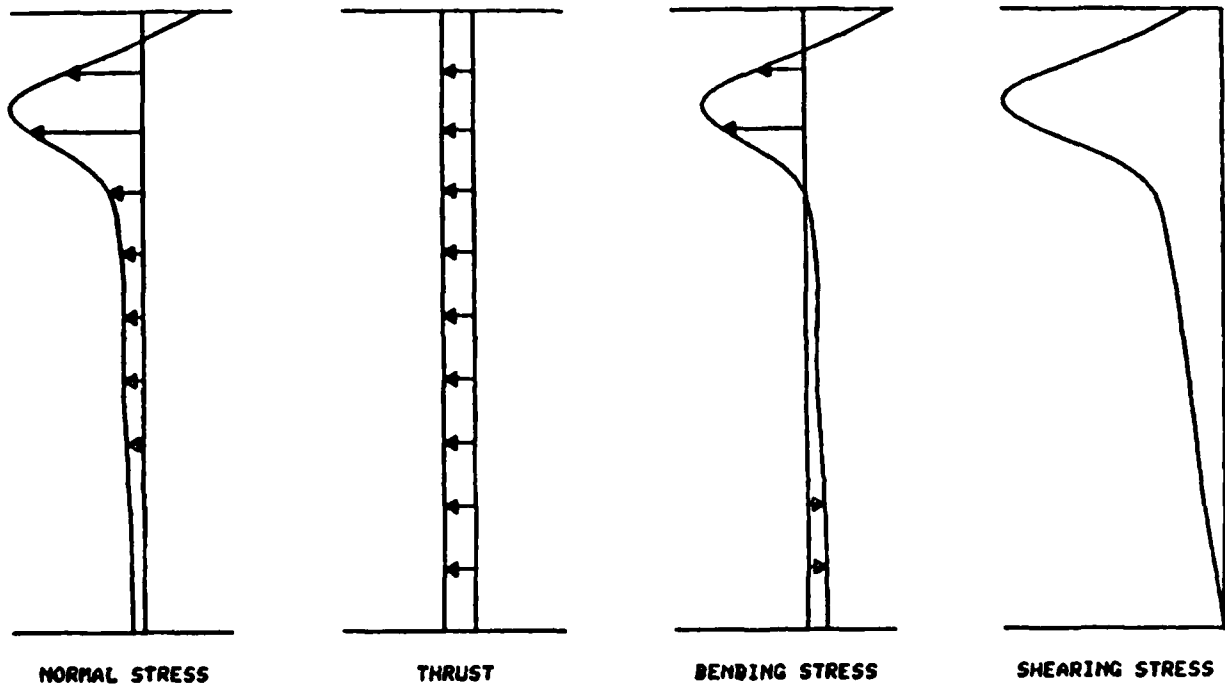
(X1, Y1) = (52., 1.)  
 (X2, Y2) = (52., 11.)  
 NEUTRAL AXIS = (52., 8.483)  
 SHEAR = .0991  
 MOMENT = .1217  
 THRUST = -.2721

Figure A10. Load case 1B (section 10)



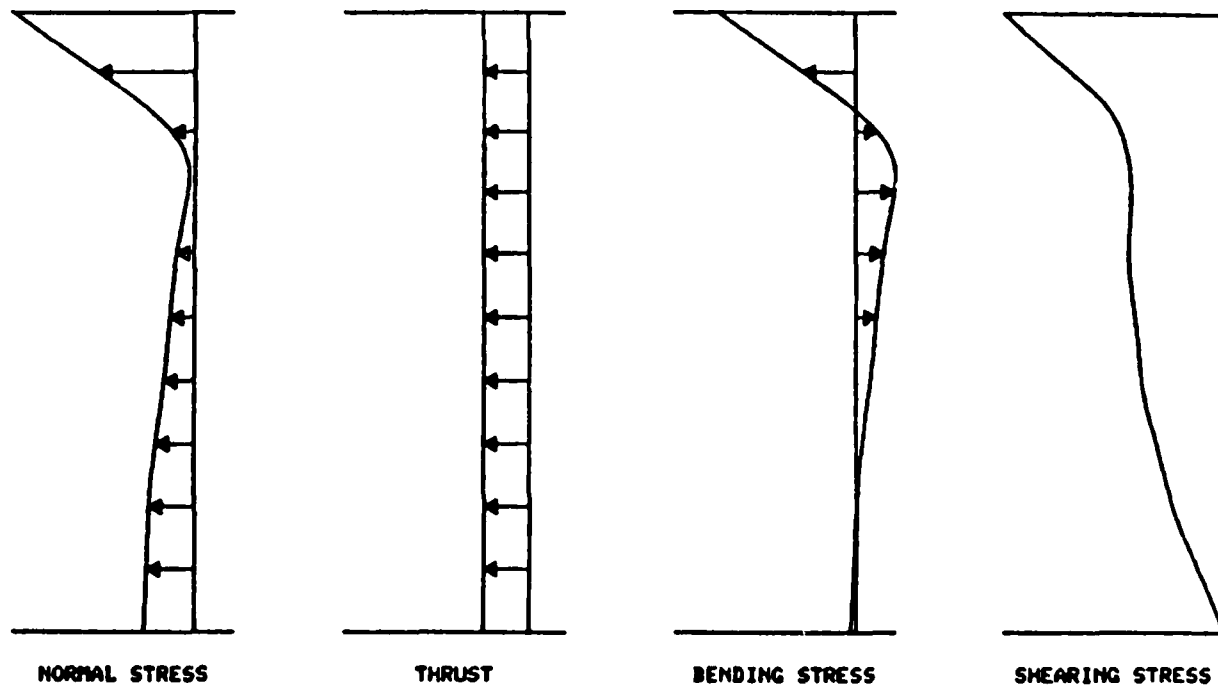
(X1, Y1) = (58.,2.)  
 (X2, Y2) = (58.,11.)  
 NEUTRAL AXIS = (58.,6.821)  
 SHEAR = -.0193  
 MOMENT = -.1296  
 THRUST = -.2153

Figure All. Load case 1B (section 11)



(X1, Y1) = (64.,3.)  
 (X2, Y2) = (64.,11.)  
 NEUTRAL AXIS = (64.,10.53)  
 SHEAR = -.1574  
 MOMENT = .2167  
 THRUST = -.2222

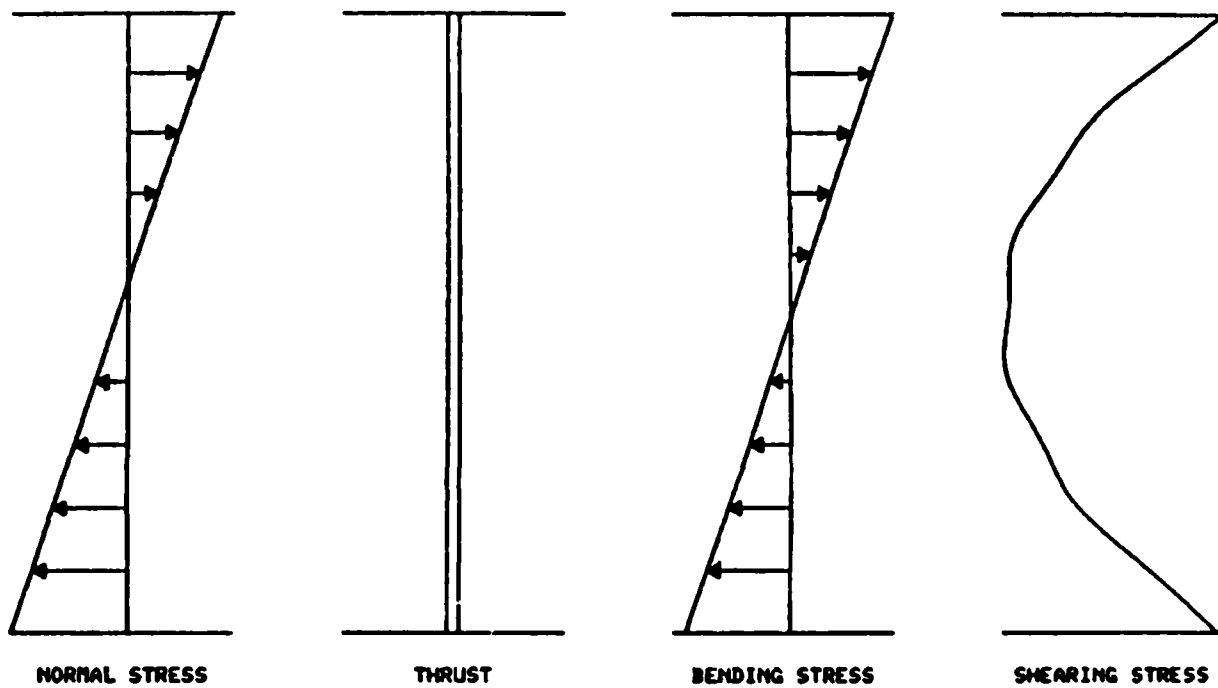
Figure A12. Load case 1B (section 12)



(X1, Y1) = (42., -1.)  
 (X2, Y2) = (42., 13.)  
 NEUTRAL AXIS = (42., 10.79)  
 SHEAR = -.542  
 MOMENT = .587  
 THRUST = -.5607

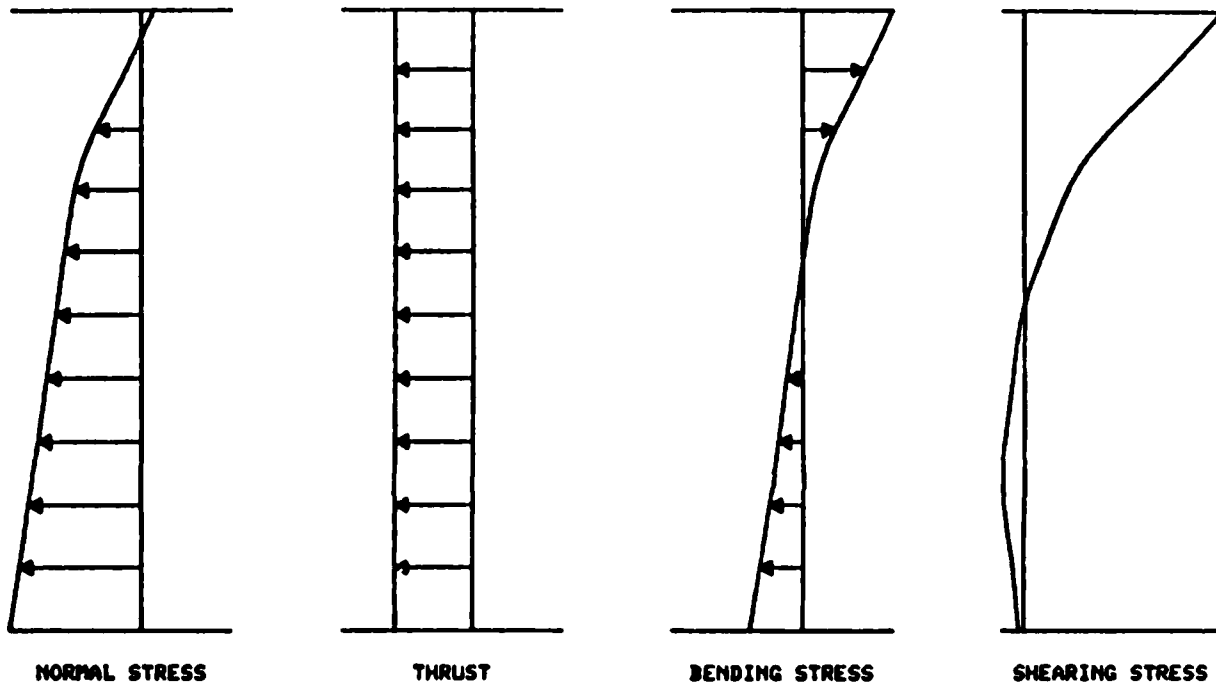
Figure A13. Load case 1B (section 13)





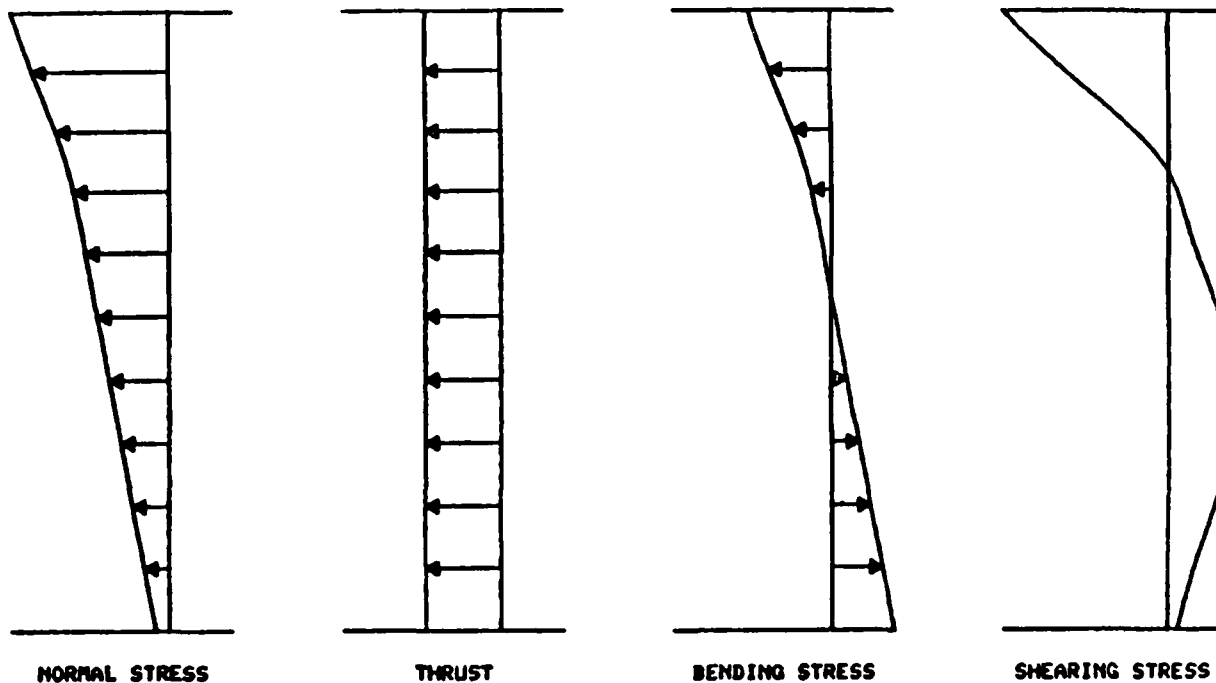
(X1, Y1) = (20., -1.)  
 (X2, Y2) = (20., 13.)  
 NEUTRAL AXIS = (20., 6.)  
 SHEAR = -2489  
 MOMENT = -7.844  
 THRUST = -.4367

Figure A14. Load case 1B (section 14)



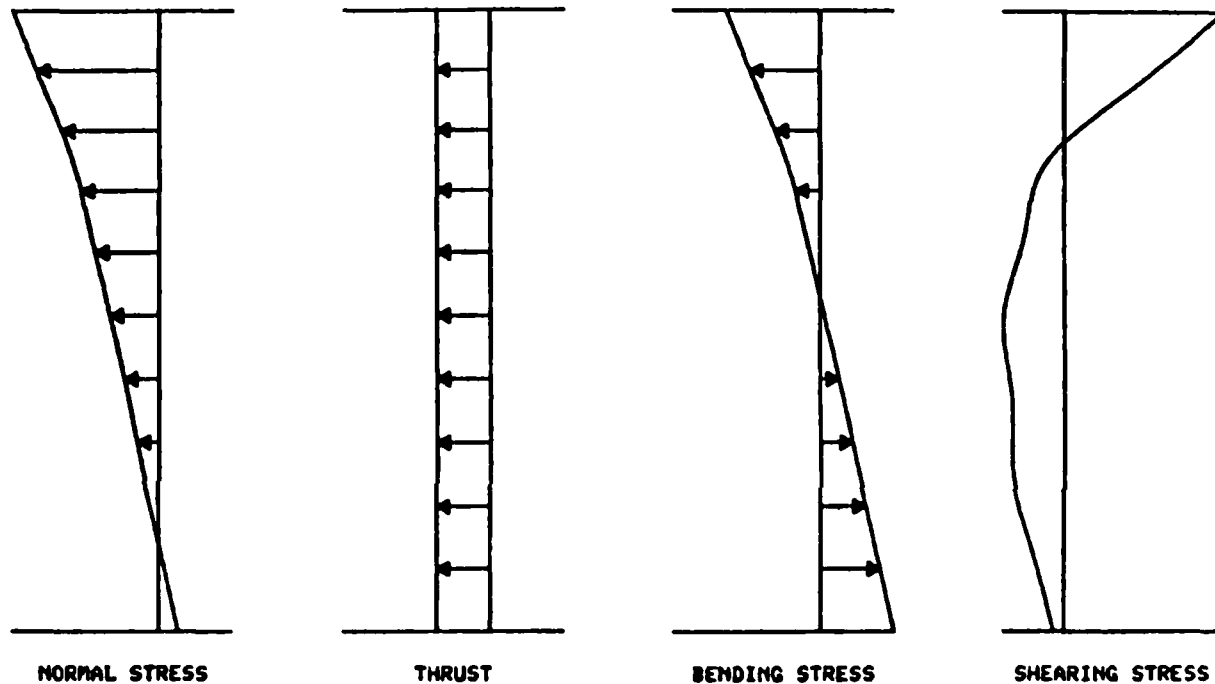
(X1, Y1) = (40., 32.)  
 (X2, Y2) = (53., 32.)  
 NEUTRAL AXIS = (47.85, 32.)  
 SHEAR = .0237  
 MOMENT = -.4094  
 THRUST = -.3025

Figure A15. Load case 1B (section 15)



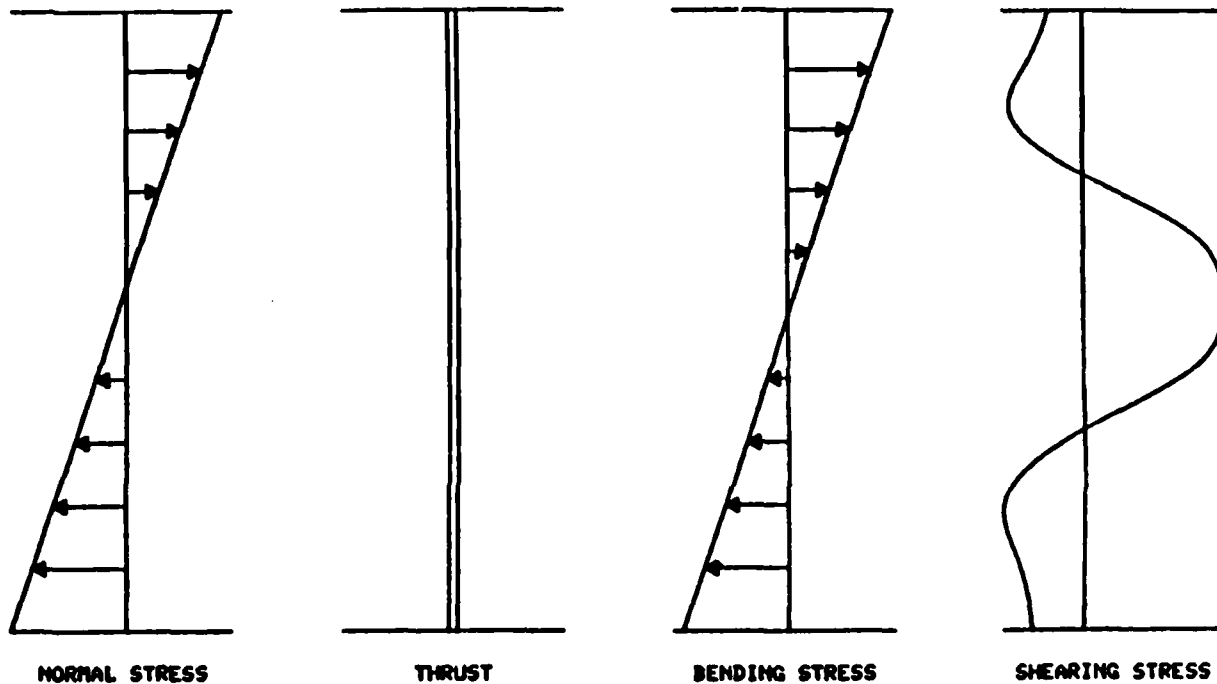
(X1, Y1) = (40.,53.)  
 (X2, Y2) = (48.,53.)  
 NEUTRAL AXIS = (44.67,53.)  
 SHEAR = .0006  
 MOMENT = .0877  
 THRUST = -.1158

Figure A16. Load case 1B (section 16)



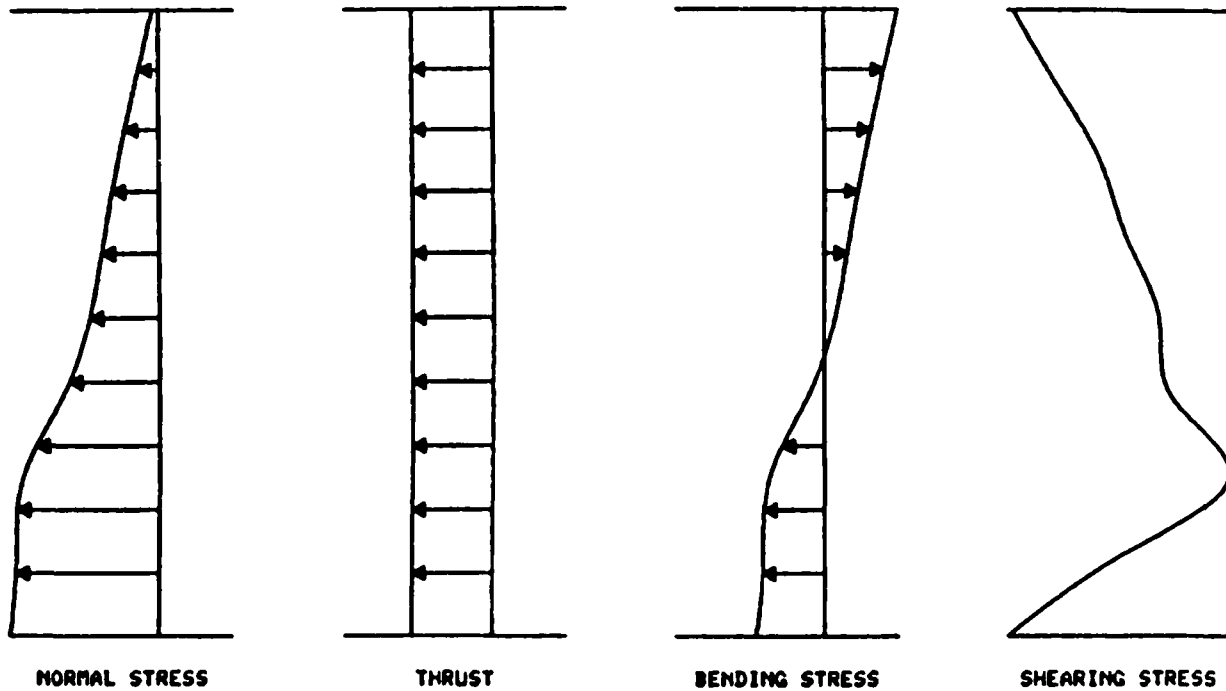
(X1, Y1) = (40.,63.)  
 (X2, Y2) = (48.,63.)  
 NEUTRAL AXIS = (44.65,63.)  
 SHEAR = -.0037  
 MOMENT = .0853  
 THRUST = -.0686

Figure A17. Load case 1B (section 17)



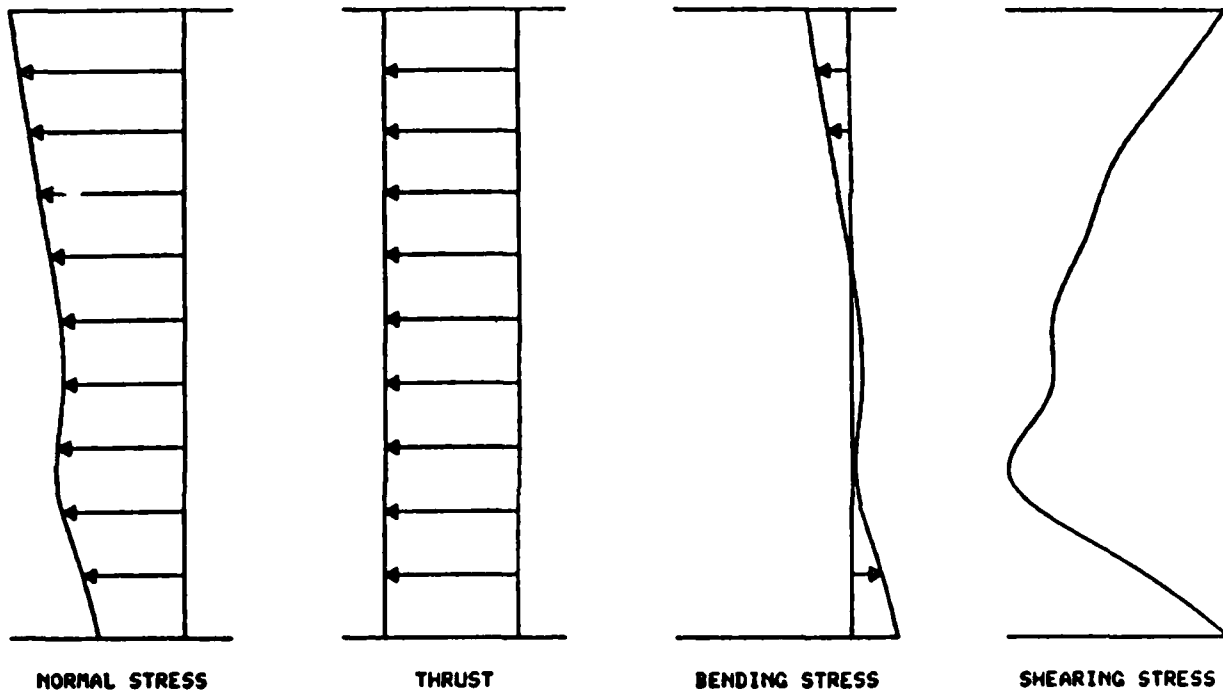
(X1, Y1) = (0., -1.)  
 (X2, Y2) = (0., 13.)  
 NEUTRAL AXIS = (0., 6.)  
 SHEAR = .6885E-4  
 MOMENT = -10.14  
 THRUST = -.4367

Figure A18. Load case 1B (section 18)



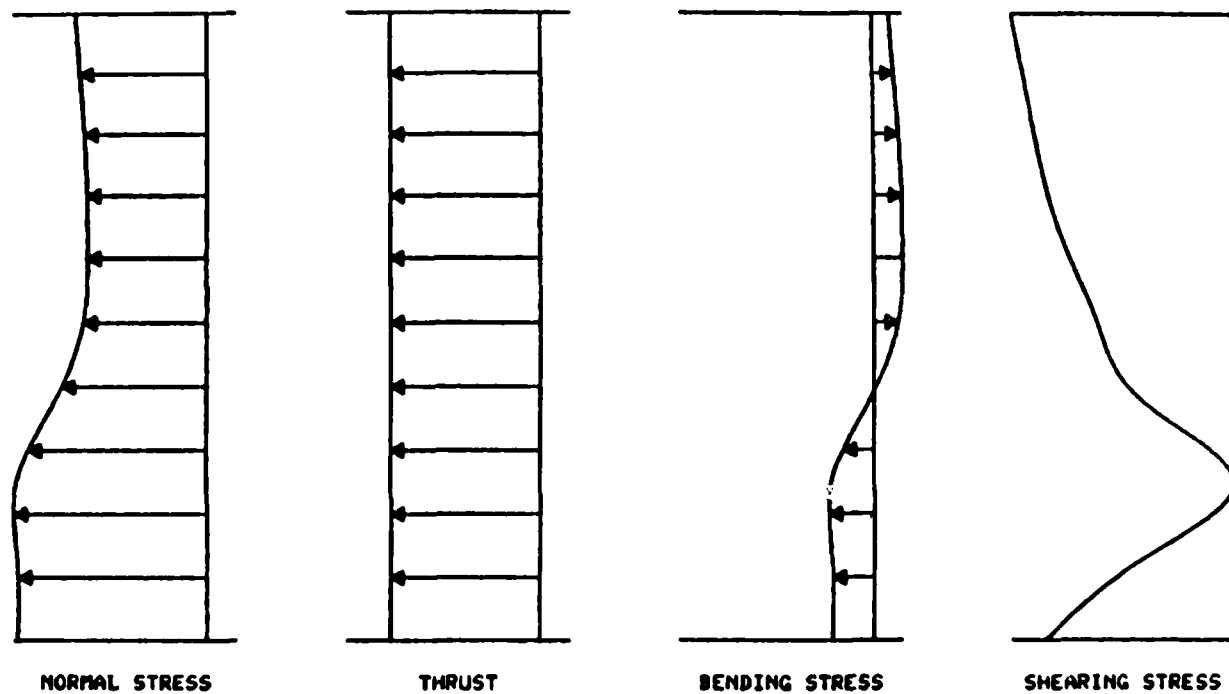
(X1, Y1) = (62.,11.)  
 (X2, Y2) = (70.,11.)  
 NEUTRAL AXIS = (65.81,11.)  
 SHEAR = .0878  
 MOMENT = -.1303  
 THRUST = -.1956

Figure A19. Load case 1B (section 1A)



(X1, Y1) • (62., 21.)  
 (X2, Y2) • (70., 21.)  
 NEUTRAL AXIS • (66.33, 21.)  
 SHEAR • -.0456  
 MOMENT • .0282  
 THRUST • -.1534

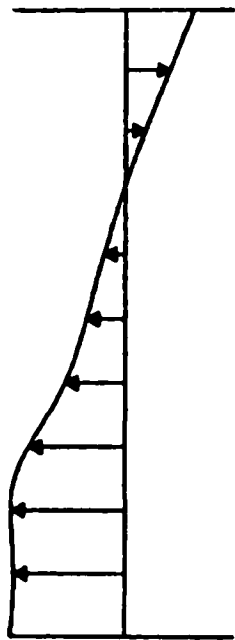
Figure A20. Load case 1B (section 2A)



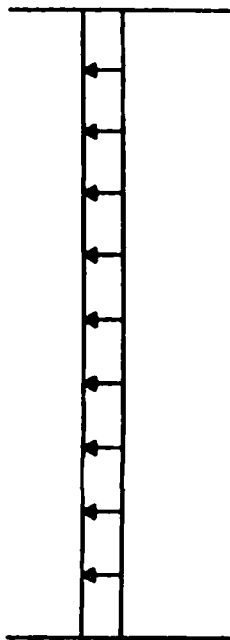
(X1, Y1) = (63.,20.)  
 (X2, Y2) = (63.,30.)  
 NEUTRAL AXIS = (63.,24.88)  
 SHEAR = .0461  
 MOMENT = -.0415  
 THRUST = -.1138

Figure A21. Load case 1B (section 3A)

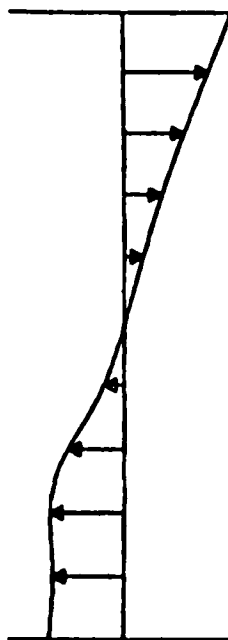




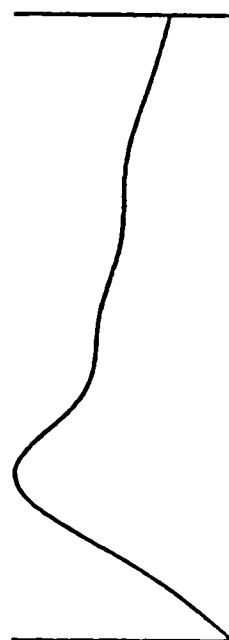
NORMAL STRESS



THRUST



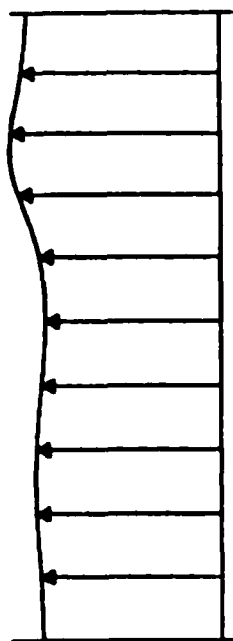
BENDING STRESS



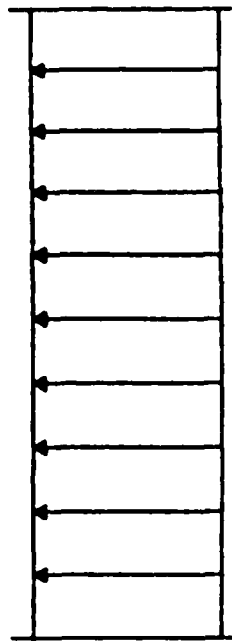
SHEARING STRESS

(X1, Y1) • (54.,20.)  
 (X2, Y2) • (54.,33.)  
 NEUTRAL AXIS • (54.,26.7)  
 SHEAR • -.1523  
 MOMENT • -.5497  
 THRUST • -.1375

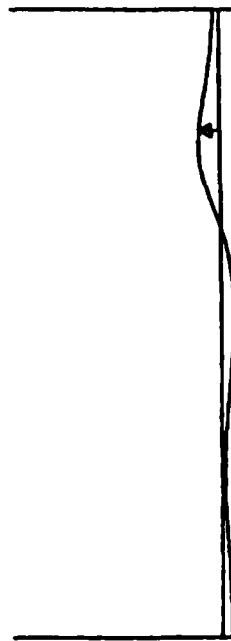
Figure A22. Load case 1B (section 4A)



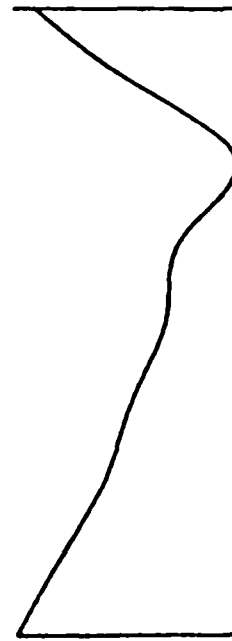
**NORMAL STRESS**



**THRUST**



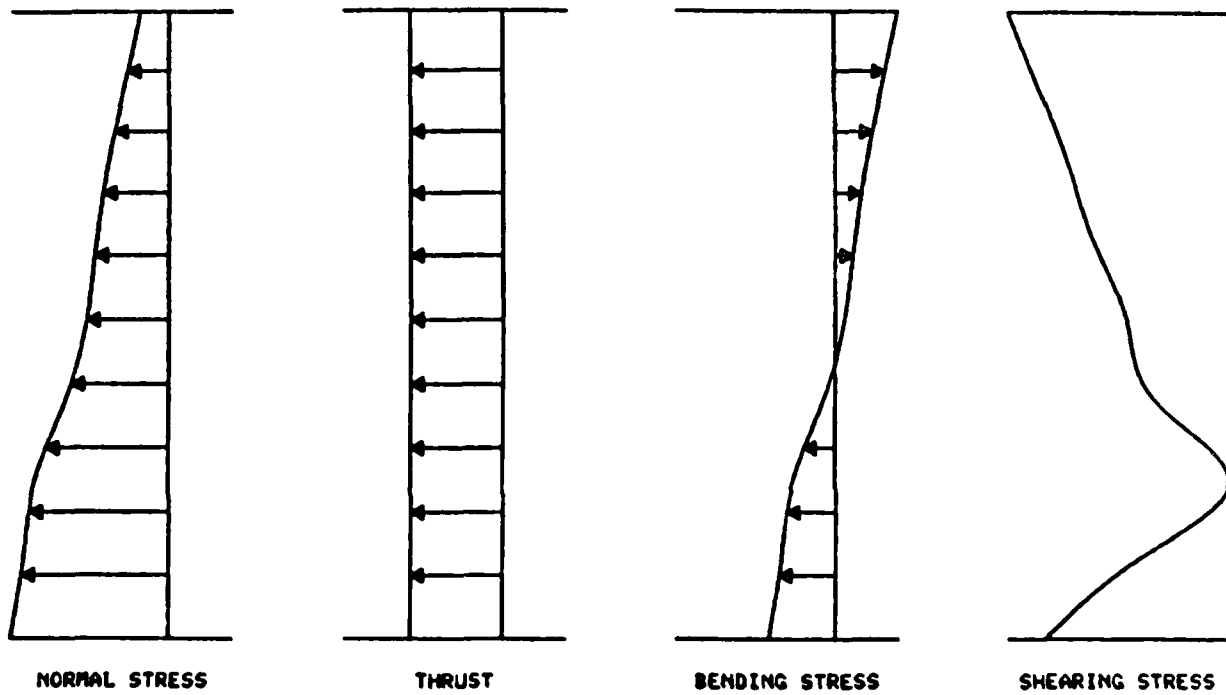
**BENDING STRESS**



**SHEARING STRESS**

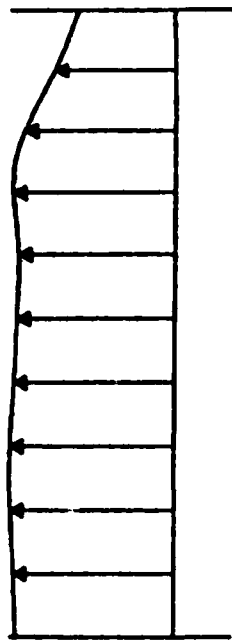
(X1, Y1) • (40.,20.)  
 (X2, Y2) • (54.,20.)  
 NEUTRAL AXIS • (48.41,20.)  
 SHEAR • .1708  
 MOMENT • -.0718  
 THRUST • -.6061

Figure A23. Load case 1B (section 5A)

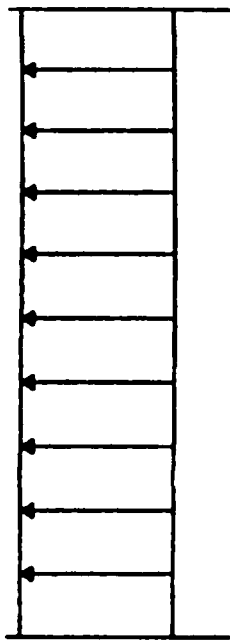


(X1, Y1) = (40.,14.)  
 (X2, Y2) = (54.,14.)  
 NEUTRAL AXIS = (46.43,14.)  
 SHEAR = .1726  
 MOMENT = -.8232  
 THRUST = -.6674

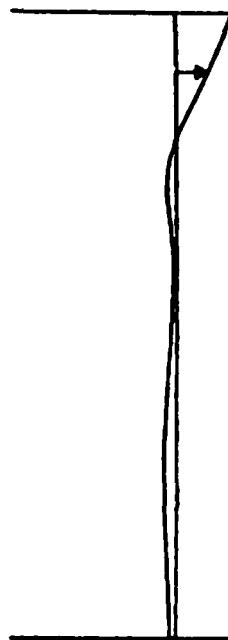
Figure A24. Load case 1B (section 6A)



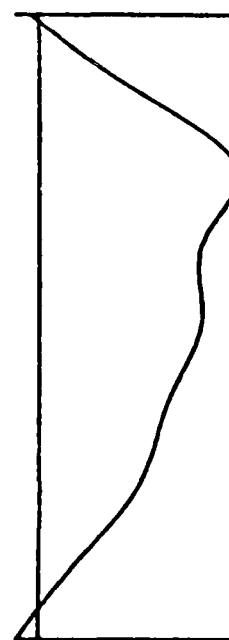
**NORMAL STRESS**



**THRUST**



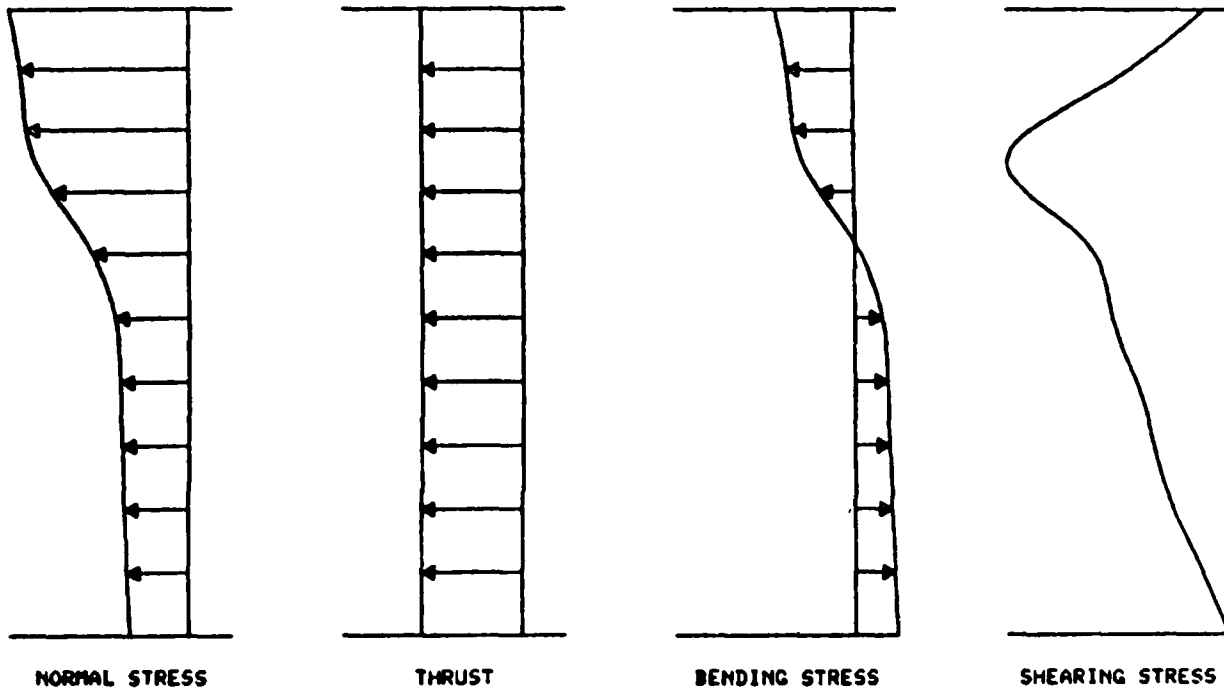
**BENDING STRESS**



**SHEARING STRESS**

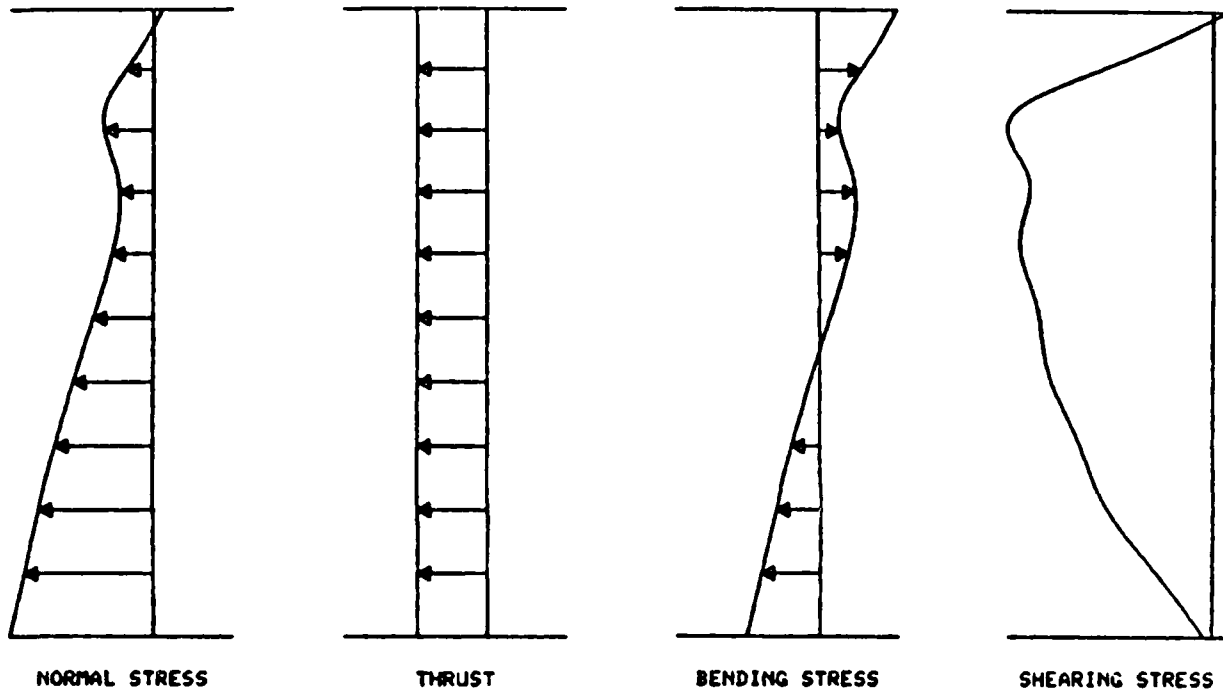
(X1, Y1) = (54.,1.)  
 (X2, Y2) = (54.,11.)  
 NEUTRAL AXIS = (54.,8.308)  
 SHEAR = .0493  
 MOMENT = -.0426  
 THRUST = -.2315

Figure A25. Load case 1B (section 7A)



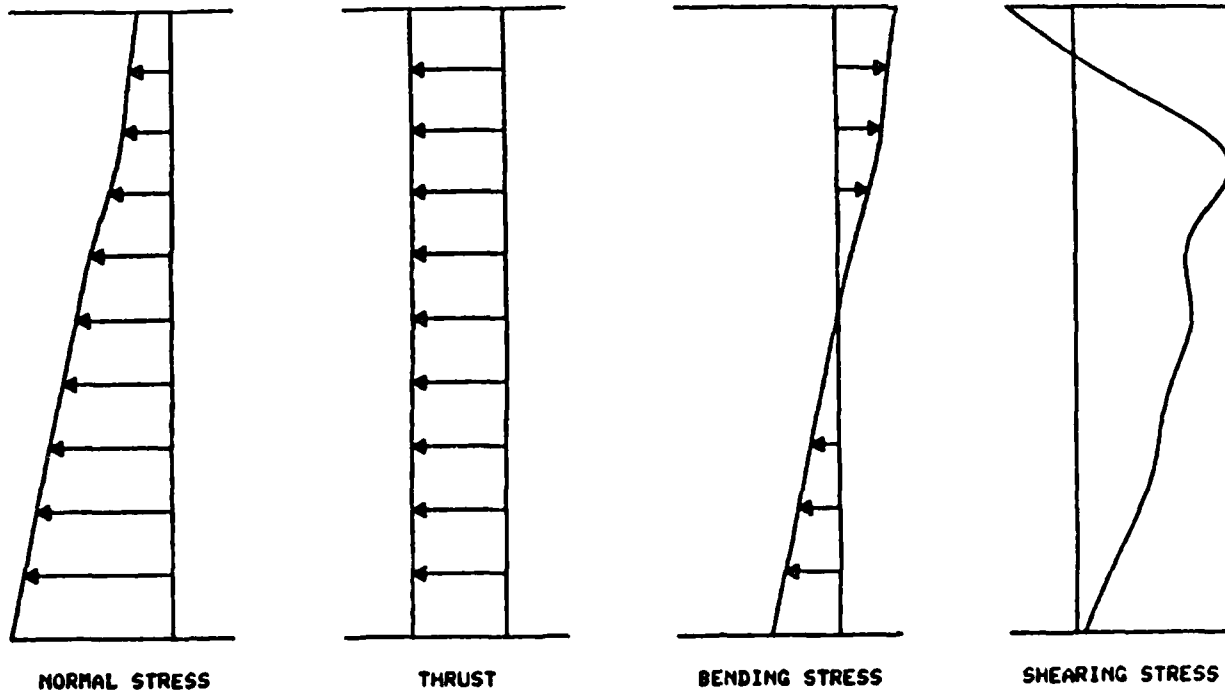
(X1, Y1) = (63.,3.)  
 (X2, Y2) = (63.,11.)  
 NEUTRAL AXIS = (63.,7.685)  
 SHEAR = -.1112  
 MOMENT = .1368  
 THRUST = -.1975

Figure A26. Load case 1B (section 8A)



(X1, Y1) = (40., -1.)  
 (X2, Y2) = (40., 13.)  
 NEUTRAL AXIS = (40., 5.398)  
 SHEAR = -.4748  
 MOMENT = -.8707  
 THRUST = -.447

Figure A27. Load case 1B (section 9A)



**NORMAL STRESS**

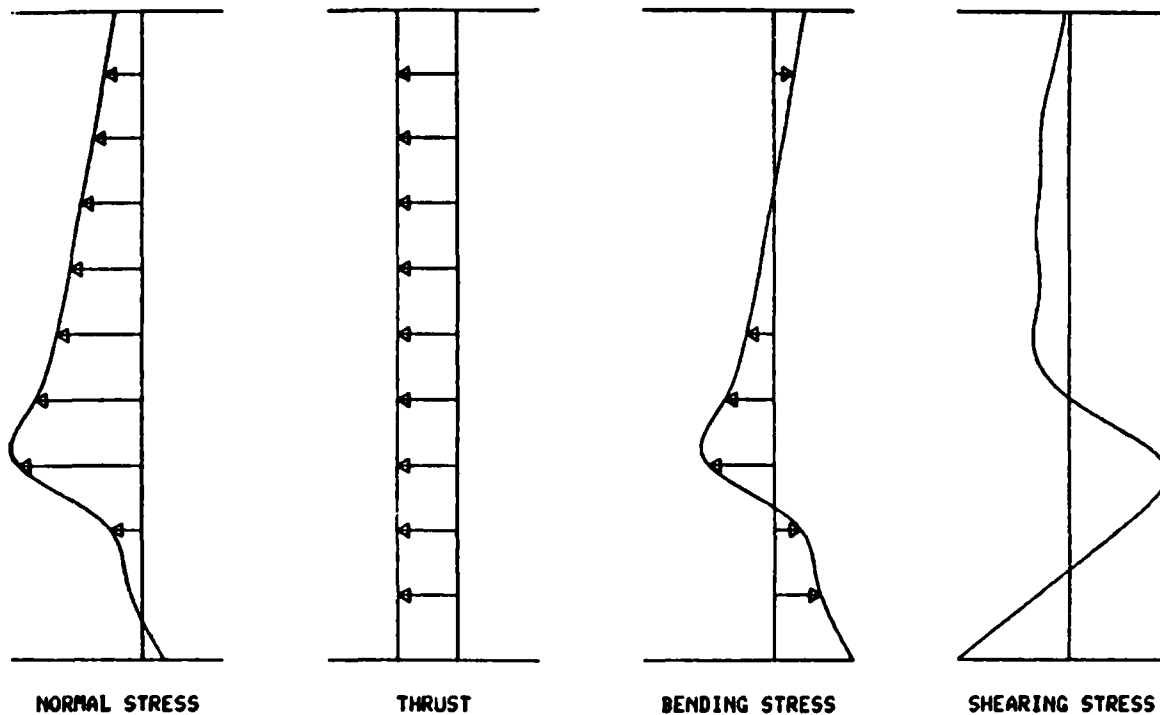
**THRUST**

**BENDING STRESS**

**SHEARING STRESS**

(X1, Y1) = (40., 36.)  
 (X2, Y2) = (52., 36.)  
 NEUTRAL AXIS = (46.58, 36.)  
 SHEAR = .0158  
 MOMENT = -.2698  
 THRUST = -.2456

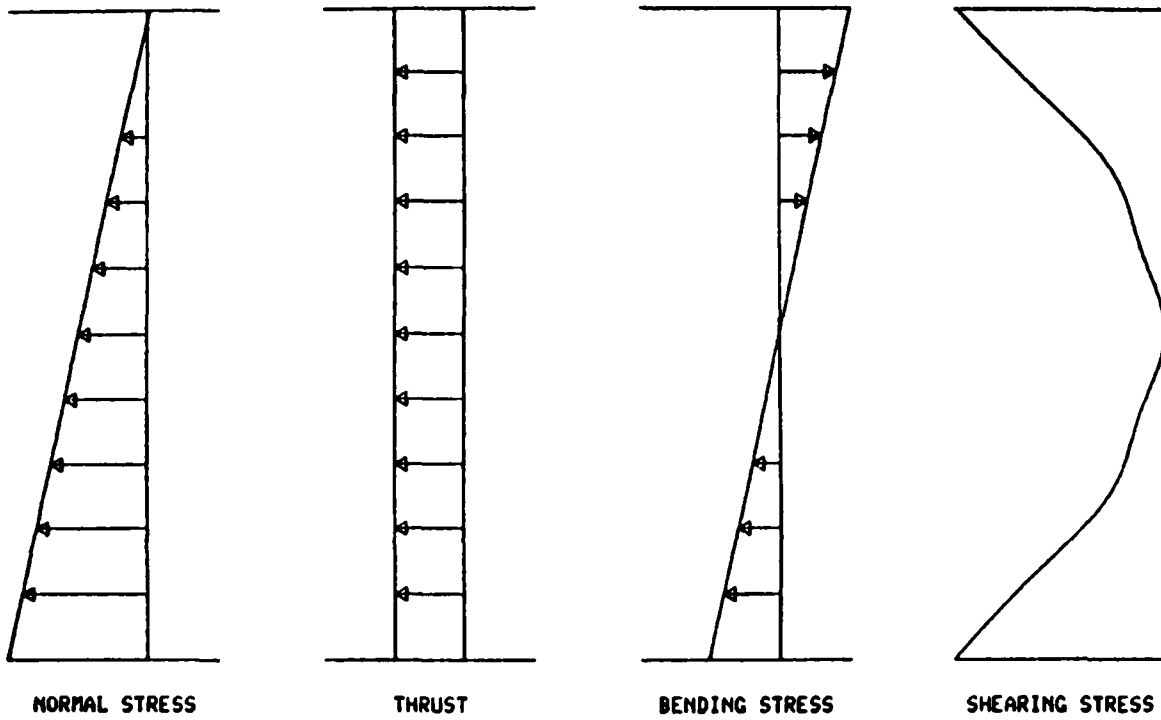
Figure A28. Load case 1B (section 10A)



(X1, Y1) = (62 .10 .)  
 (X2, Y2) = (70 .10 .)  
 NEUTRAL AXIS = (66 4.10 .)  
 SHEAR = - 0136  
 MOMENT = . 0394  
 THRUST = - .3287

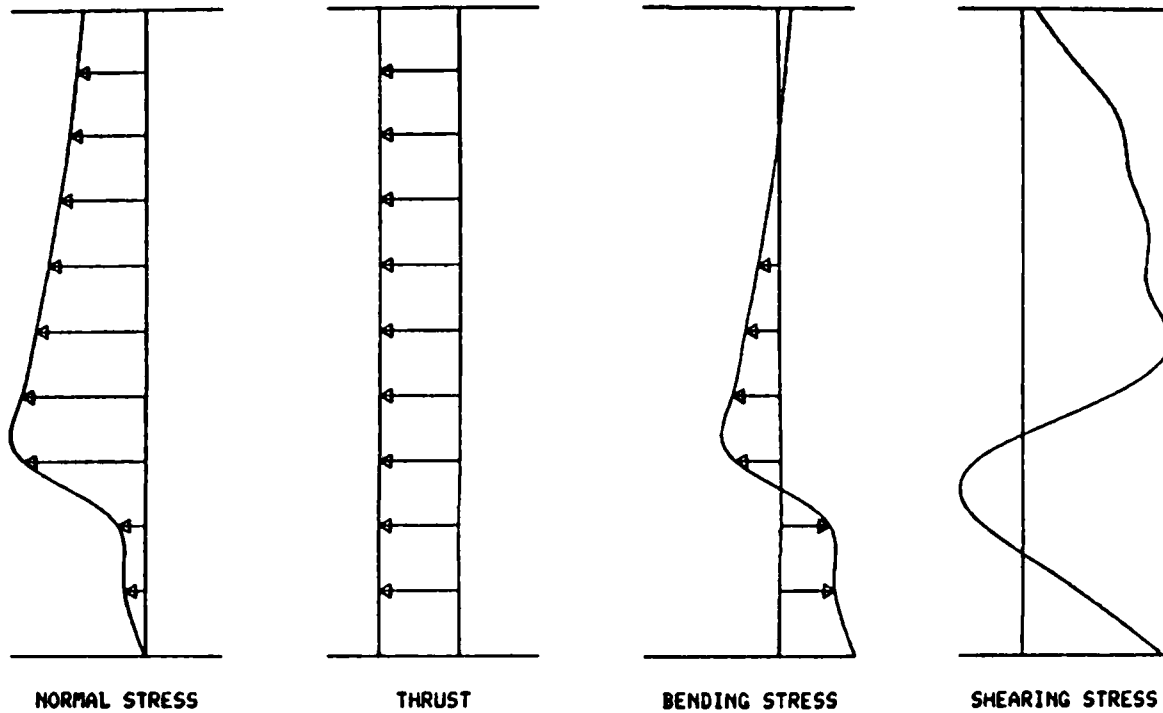
Figure A29. Load case 2B (section 1)





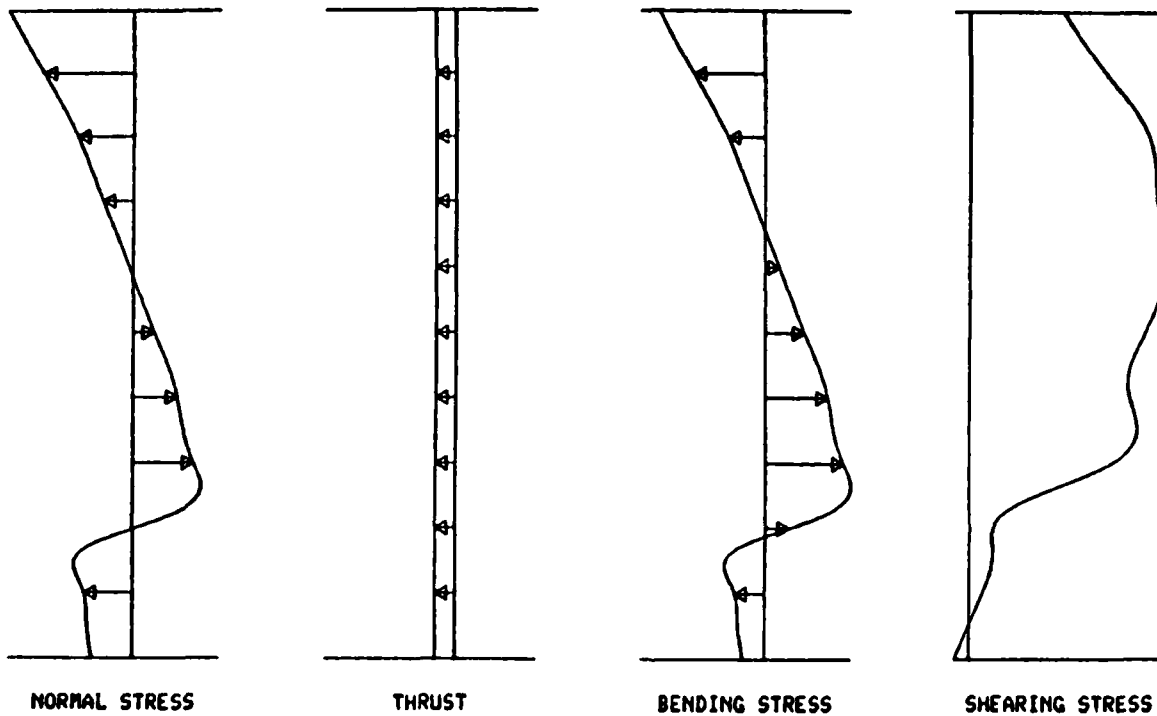
(X1, Y1) = (62, .16 )  
 (X2, Y2) = (70, .16 )  
 NEUTRAL AXIS = (66, .16 )  
 SHEAR = .0051  
 MOMENT = - .1791  
 THRUST = - .2598

Figure A30. Load case 2B (section 2)



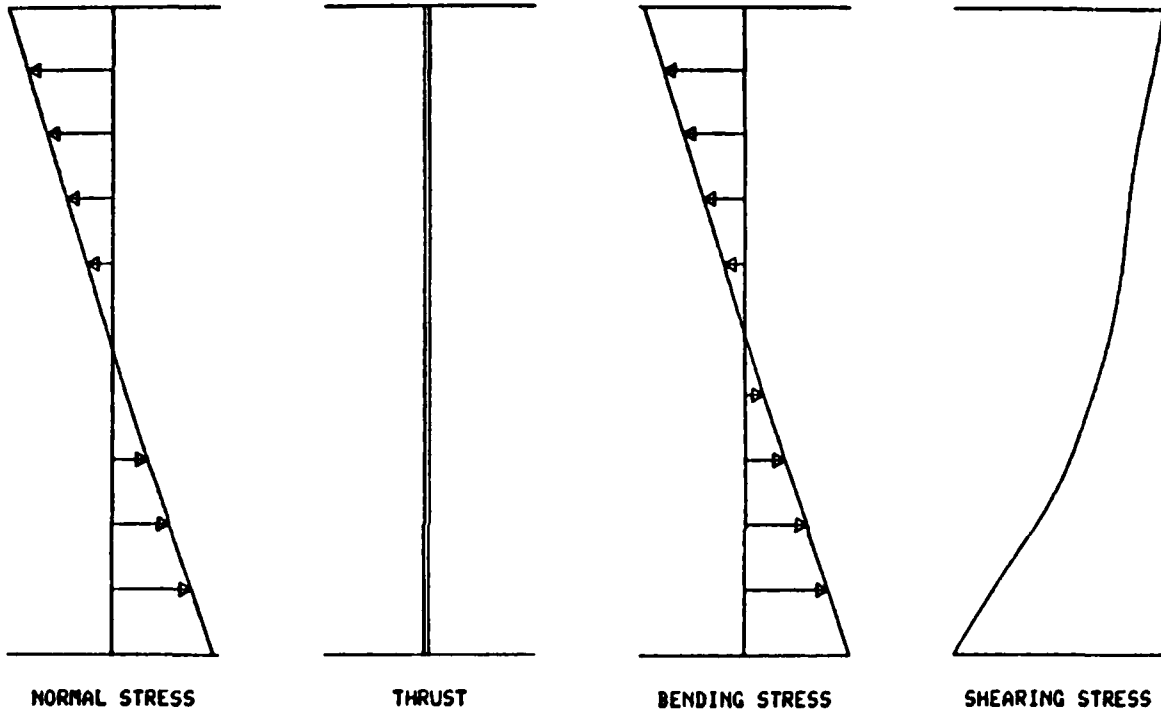
(X1, Y1) • (62 .22 )  
 (X2, Y2) • (70 .22 )  
 NEUTRAL AXIS • (66 89.22 .)  
 SHEAR • 0403  
 MOMENT • .0824  
 THRUST • - 2714

Figure A31. Load case 2B (section 3)



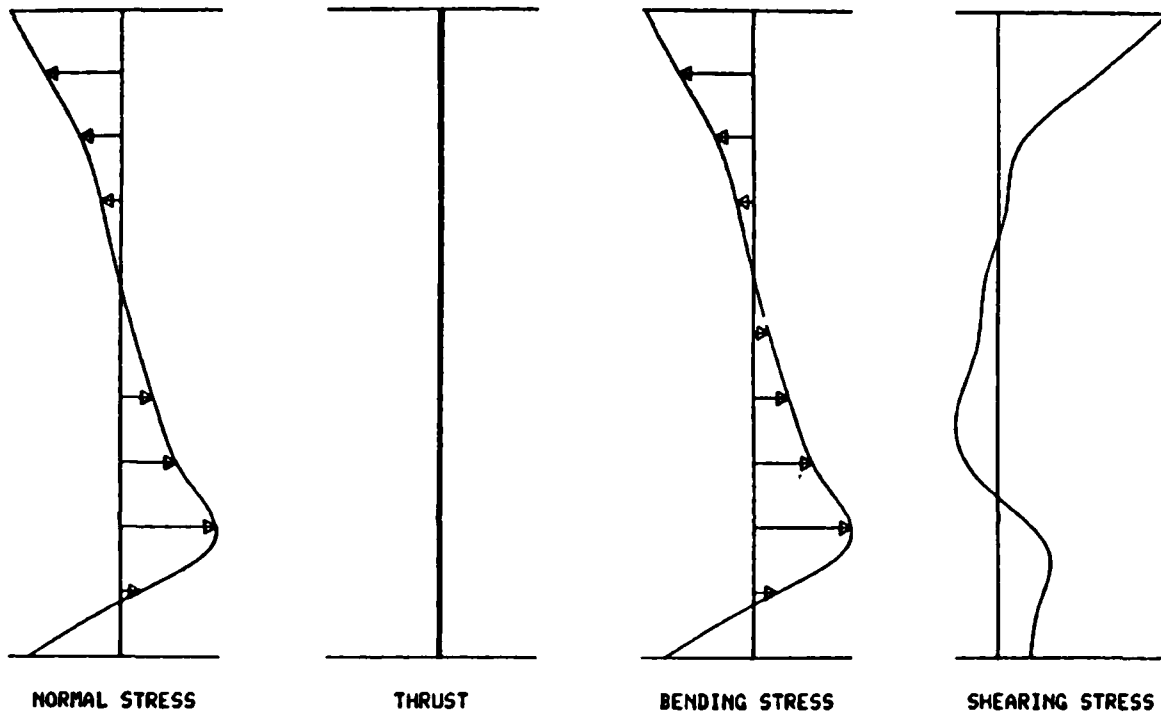
(X1, Y1) • (64 .20 .)  
 (X2, Y2) • (64 .30 .)  
 NEUTRAL AXIS • (64 .25 91)  
 SHEAR • 1499  
 MOMENT • 2424  
 THRUST • - 068

Figure A32. Load case 2B (section 4)



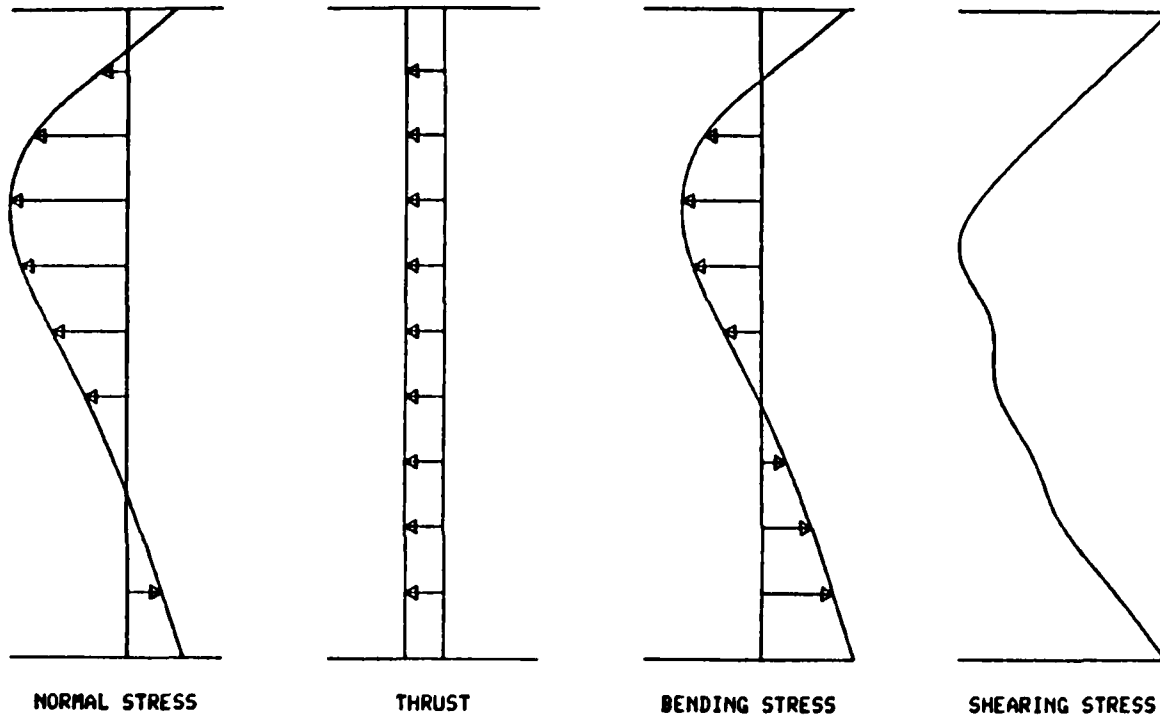
(X1, Y1) = (58 .20 )  
 (X2, Y2) = (58 .32 )  
 NEUTRAL AXIS = (58 .26.18 )  
 SHEAR = .1322  
 MOMENT = 1.185  
 THRUST = - .0381

Figure A33. Load case 2B (section 5)



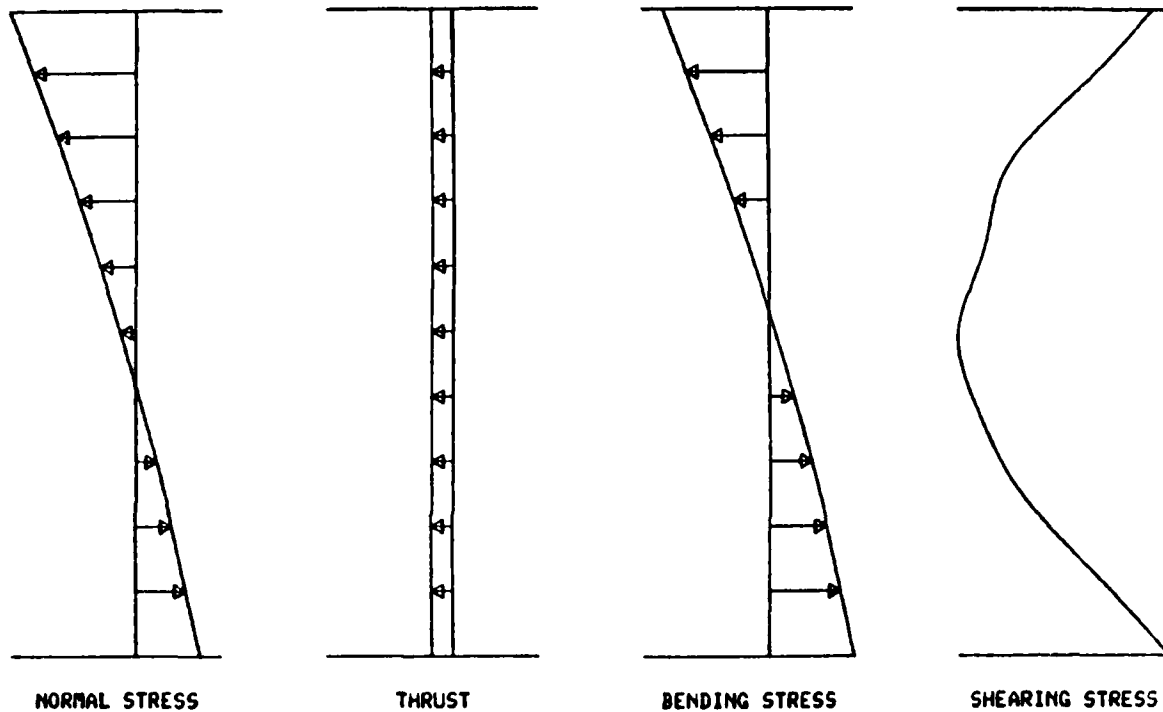
(X1, Y1) • (52 .20 )  
 (X2, Y2) • (52 .33 )  
 NEUTRAL AXIS • (52 .27 03)  
 SHEAR • .1064  
 MOMENT • 1 562  
 THRUST • - 0339

Figure A34. Load case 2B (section 6)



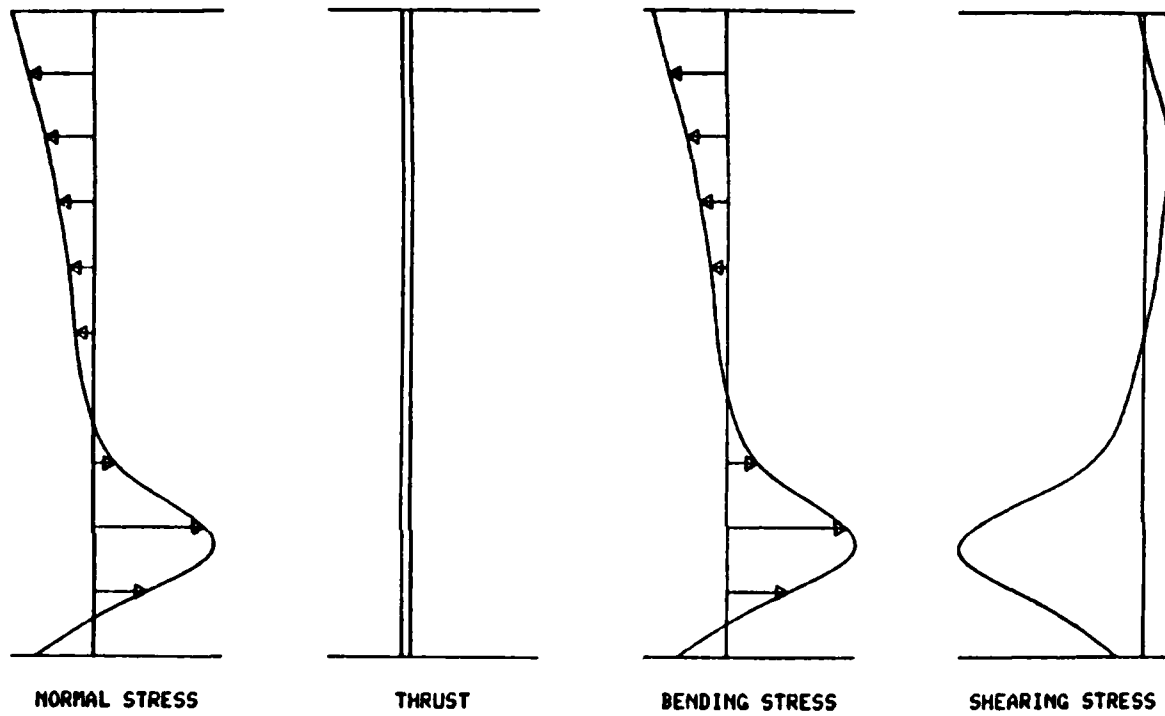
(X1, Y1) • (40 .22 )  
 (X2, Y2) • (54 .22 )  
 NEUTRAL AXIS • (52 63.22 )  
 SHEAR • - .2677  
 MOMENT • 8072  
 THRUST • -.2941

Figure A35. Load case 2B (section 7)



(X1, Y1) = (40, 17)  
 (X2, Y2) = (54, 17)  
 NEUTRAL AXIS = (47, 29.17)  
 SHEAR = - .2722  
 MOMENT = 2.413  
 THRUST = - .3198

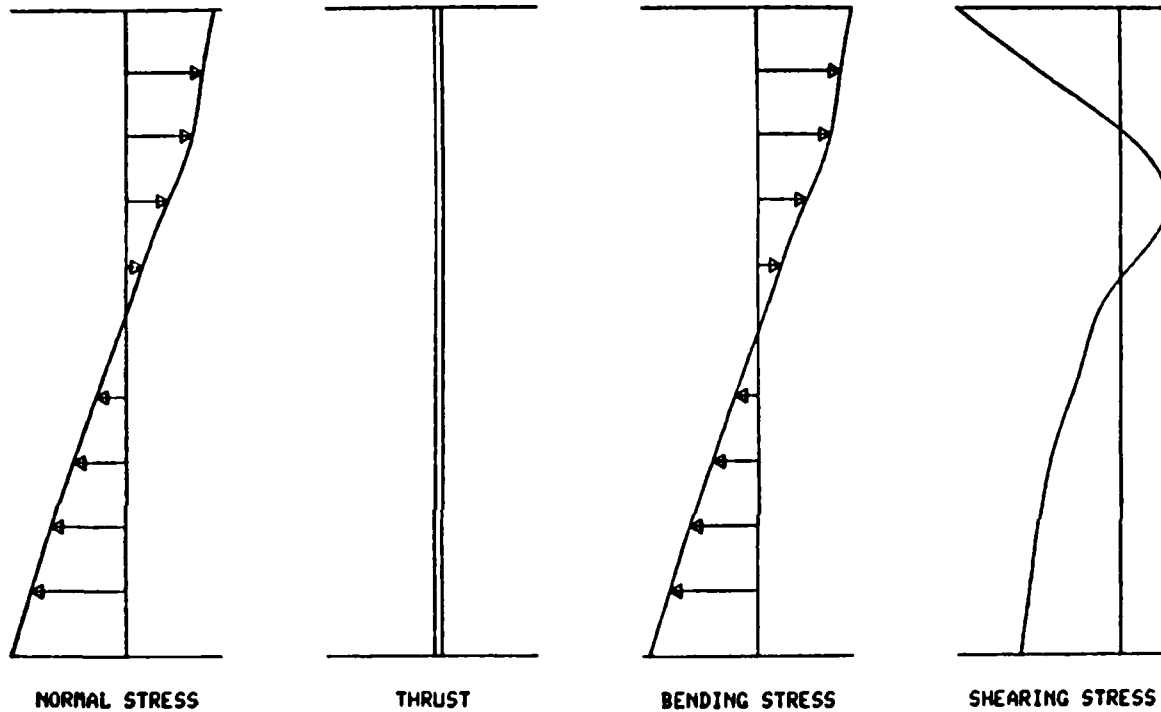
Figure A36. Load case 2B (section 8)



(X1, Y1) = (40 .12 )  
 (X2, Y2) = (54 .12 )  
 NEUTRAL AXIS = (45 01.12.)  
 SHEAR = - 405  
 MOMENT = 4 334  
 THRUST = - 2807

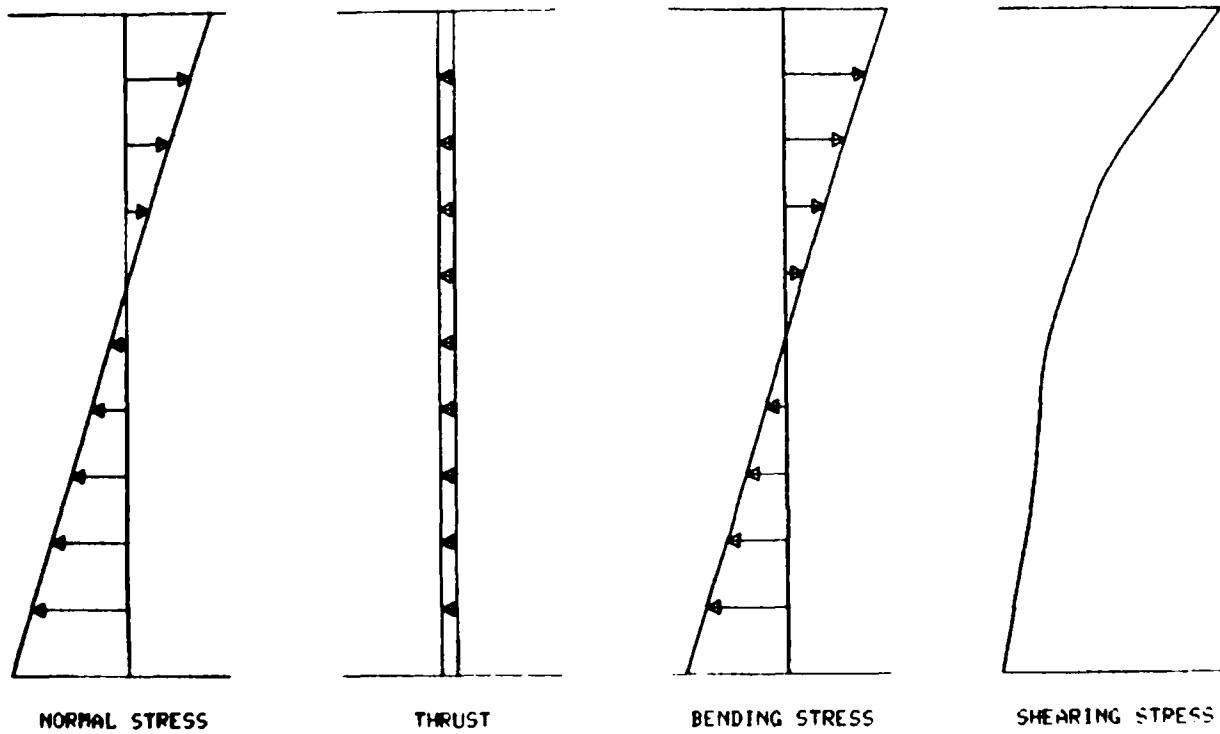
Figure A37. Load case 2B (section 9)





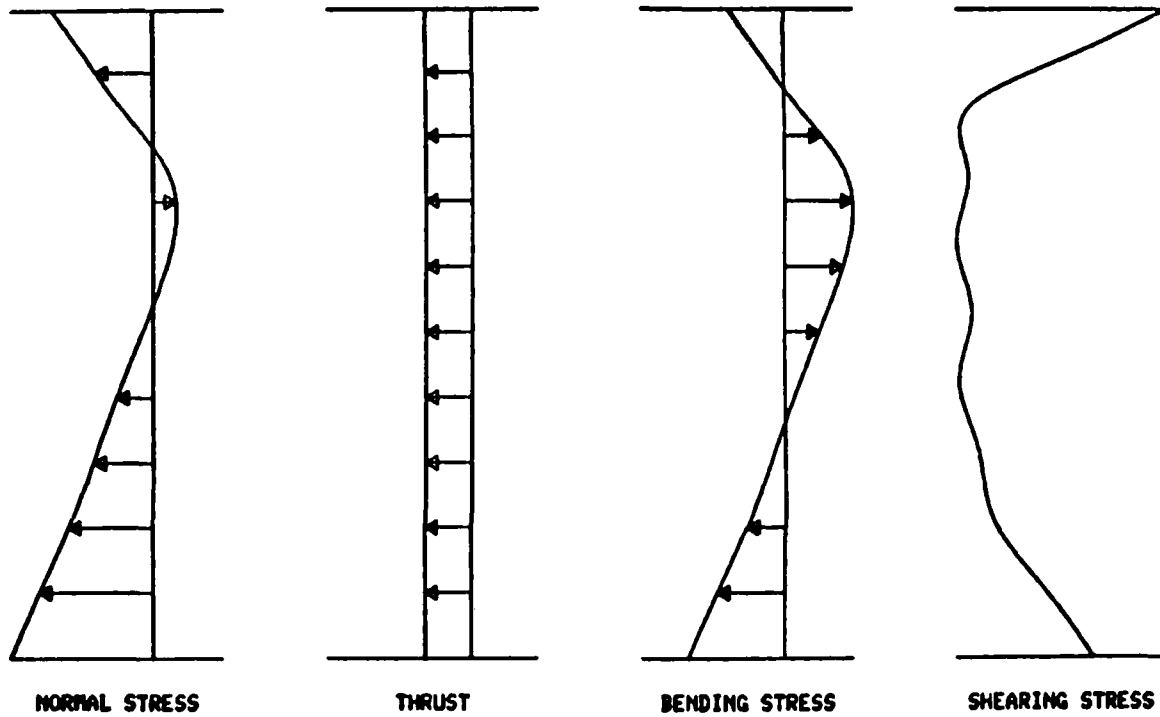
(X1, Y1) = (52 .1 )  
 (X2, Y2) = (52 .11 )  
 NEUTRAL AXIS = (52 .6 438)  
 SHEAR = - 1059  
 MOMENT = -2 025  
 THRUST = - .0865

Figure A38. Load case 2B (section 10)



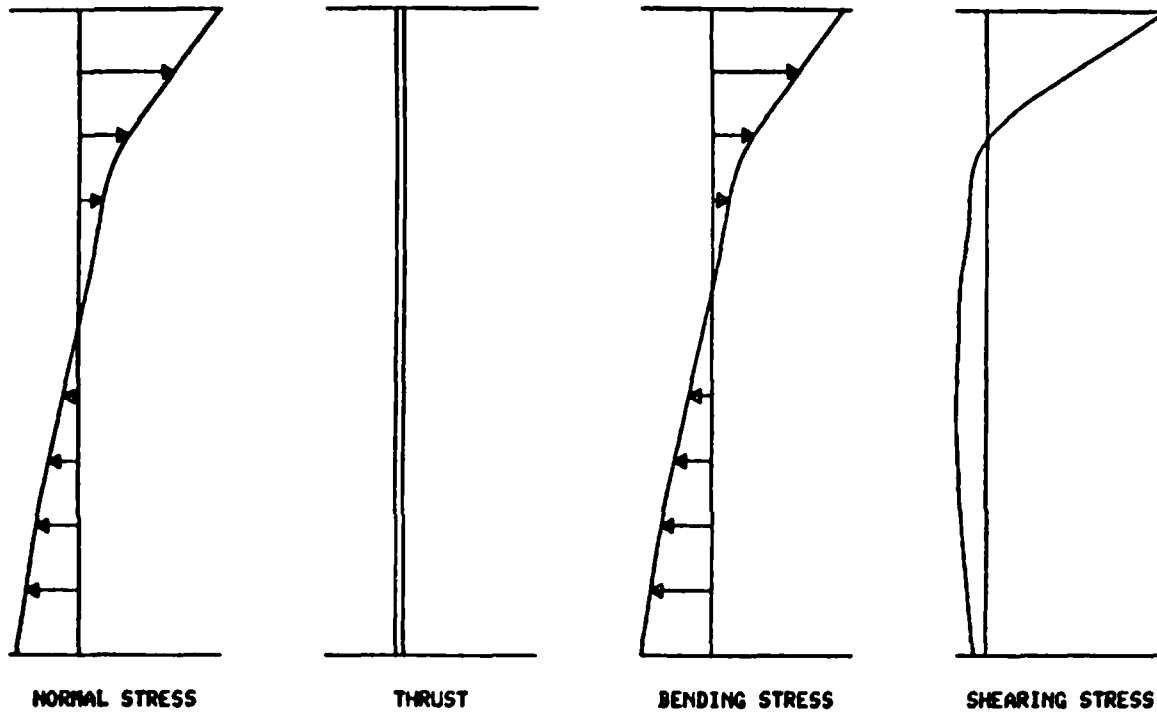
(X1, Y1) \* (58 .2 )  
 (X2, Y2) \* (58 .11 )  
 NEUTRAL AXIS \* (58 .6 557)  
 SHEAR \* - 1118  
 MOMENT \* -1 04  
 THRUST \* - 142

Figure A39. Load case 2B (section 11)



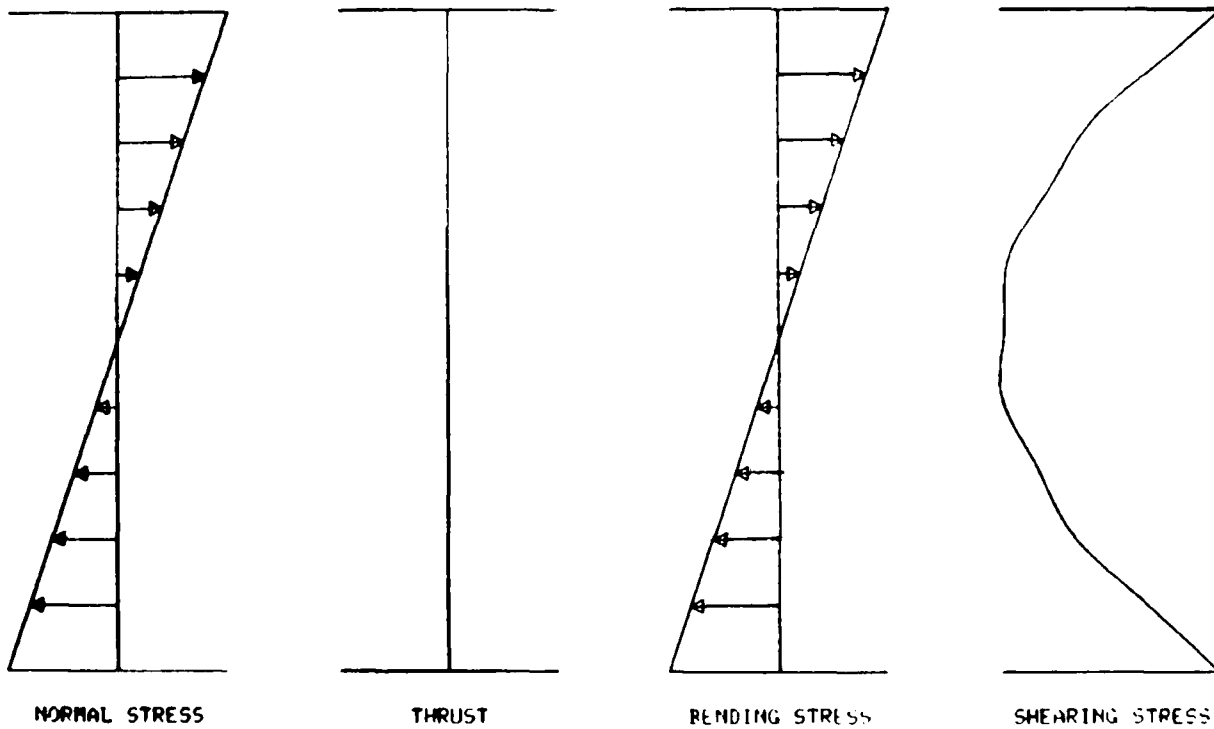
(X1, Y1) = (64.3.)  
 (X2, Y2) = (64.11.)  
 NEUTRAL AXIS = (64.10.15)  
 SHEAR = -.1668  
 MOMENT = -.1692  
 THRUST = -.1493

Figure A40. Load case 2B (section 12)



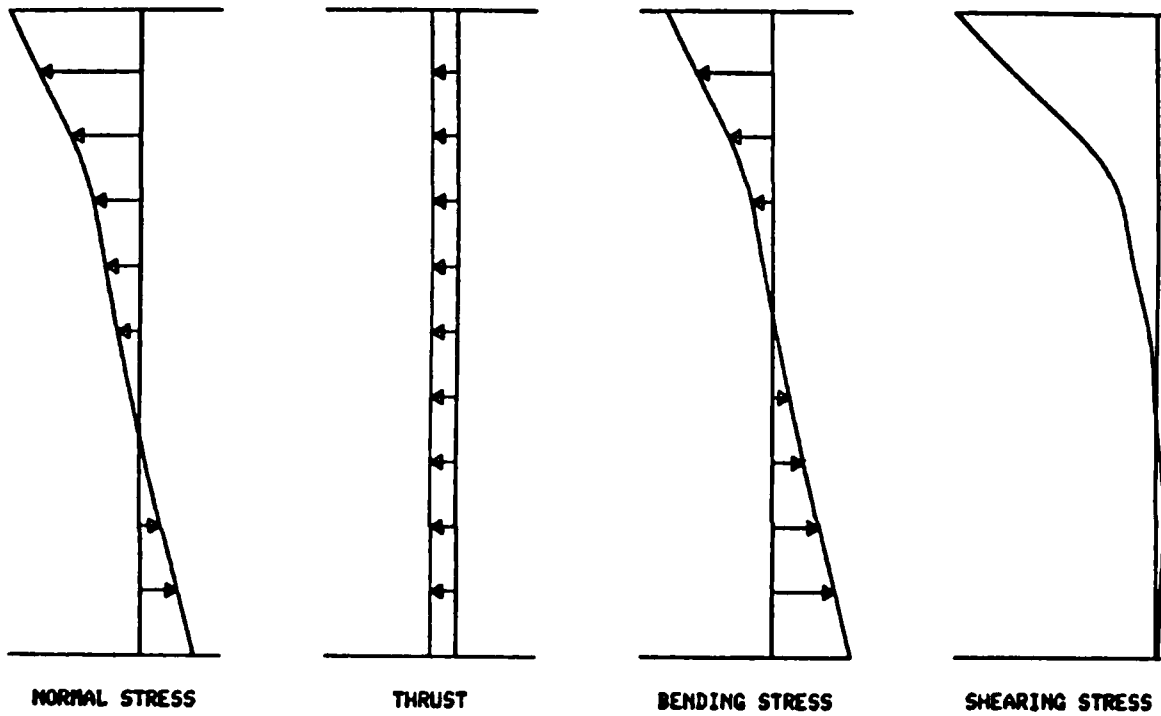
(X1, Y1) = (42., -1.)  
 (X2, Y2) = (42., 13.)  
 NEUTRAL AXIS = (42., 7.31)  
 SHEAR = -.0111  
 MOMENT = -10.89  
 THRUST = .4203

Figure A41. Load case 2B (section 13)



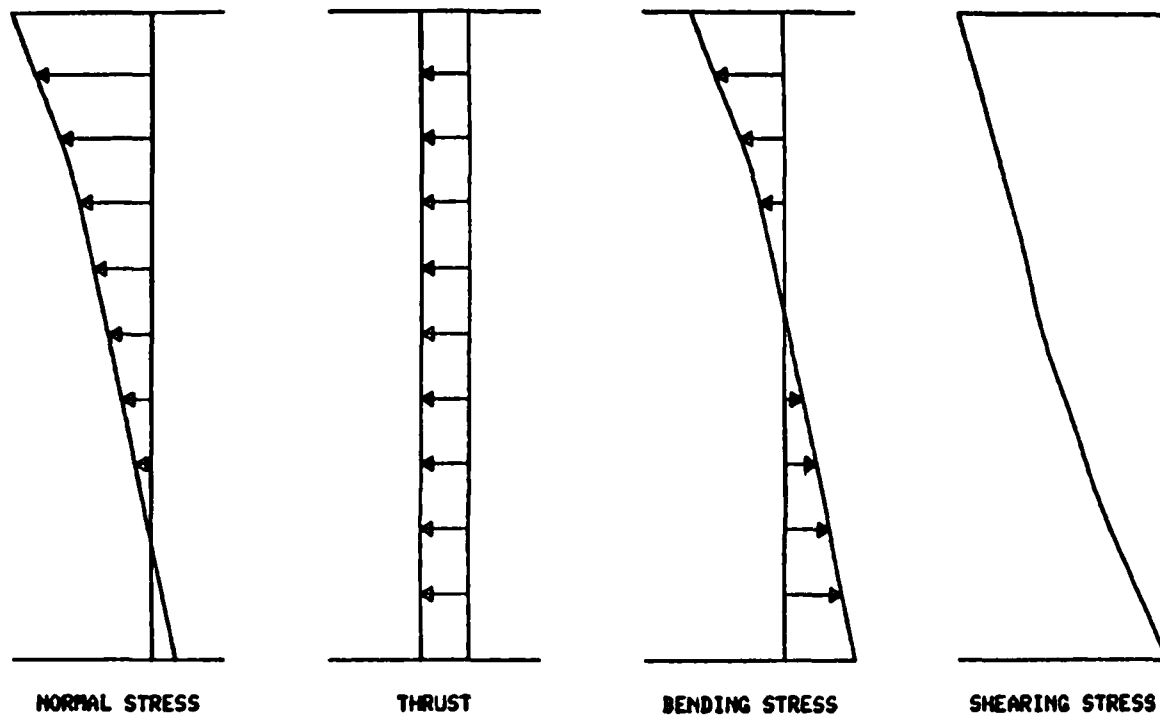
(X1, Y1) = (20, -1 )  
 (X2, Y2) = (20, 13 )  
 NEUTRAL AXIS = (20, 6 )  
 SHEAR = - 0901  
 MOMENT = -11 23  
 THRUST = - 0003

Figure A42. Load case 2B (section 14)



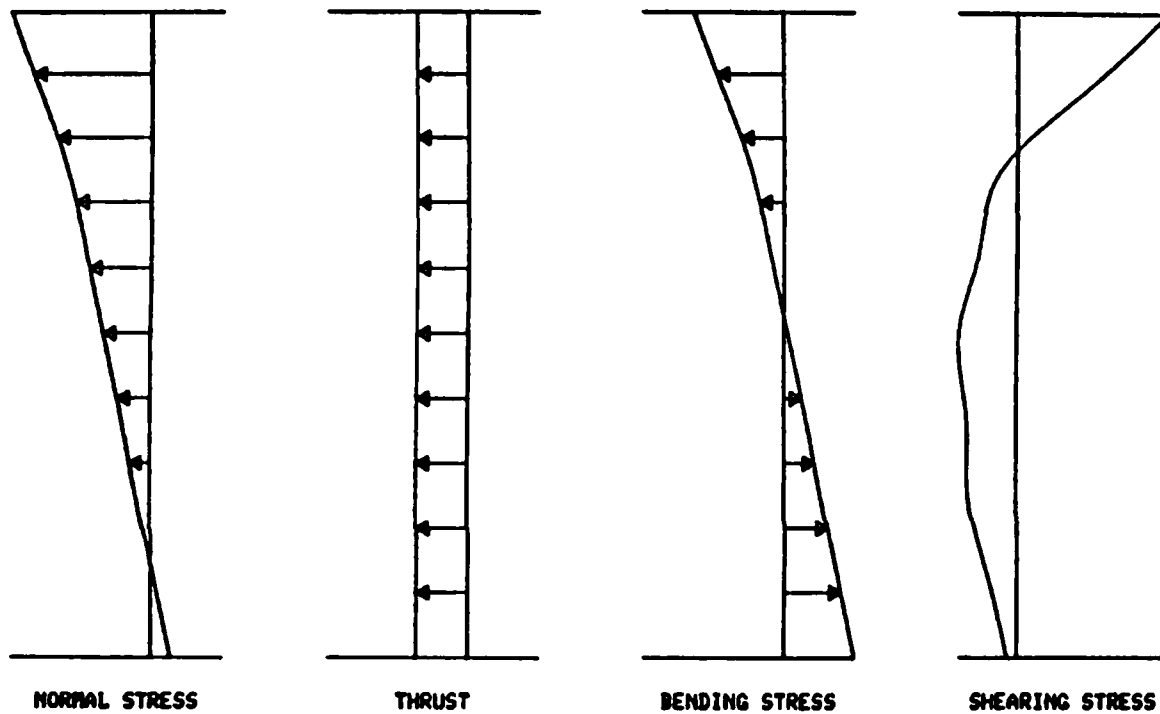
(X1, Y1) • (40 .32.)  
 (X2, Y2) • (53 .32.)  
 NEUTRAL AXIS • (47.3.32.)  
 SHEAR • -.1131  
 MOMENT • 1.42  
 THRUST • -.2629

Figure A43. Load case 2B (section 15)



(X1, Y1) • (40., 53.)  
 (X2, Y2) • (48., 53.)  
 NEUTRAL AXIS • (44.66, 53.)  
 SHEAR • -.0225  
 MOMENT • .1581  
 THRUST • -.1156

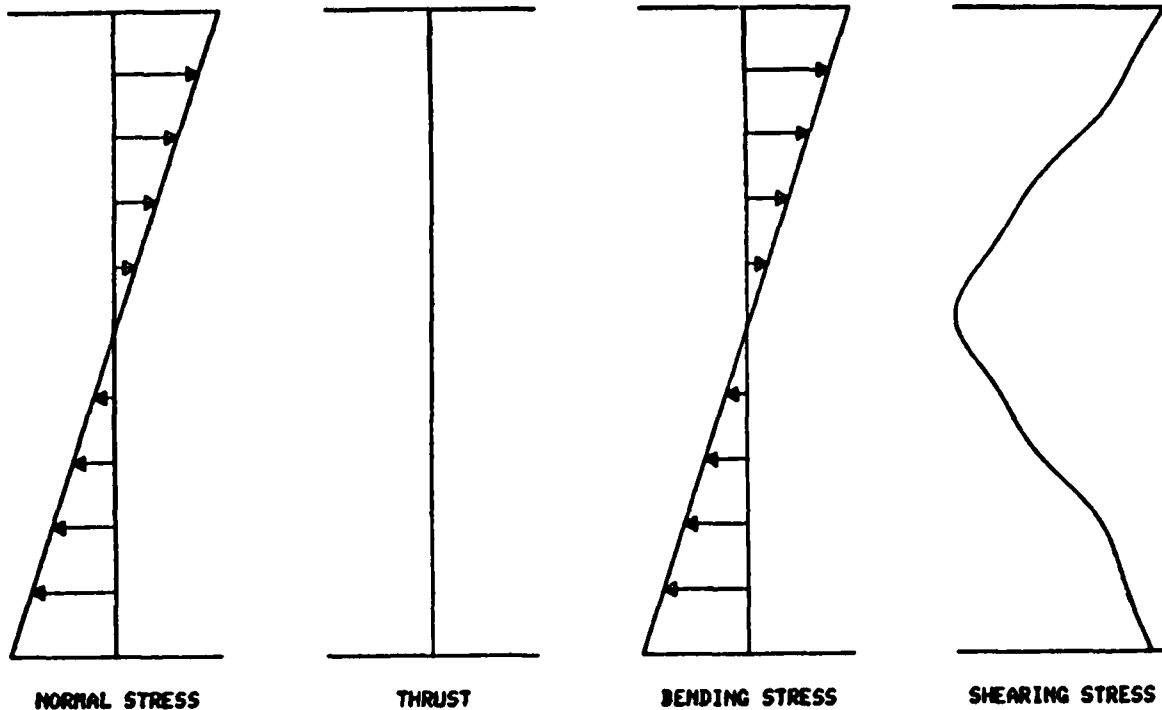
Figure A44. Load case 2B (section 16)



(X1, Y1) = (40.63.)  
 (X2, Y2) = (48.63.)  
 NEUTRAL AXIS = (44.64.63.)  
 SHEAR = -.0036  
 MOMENT = .085  
 THRUST = -.0686

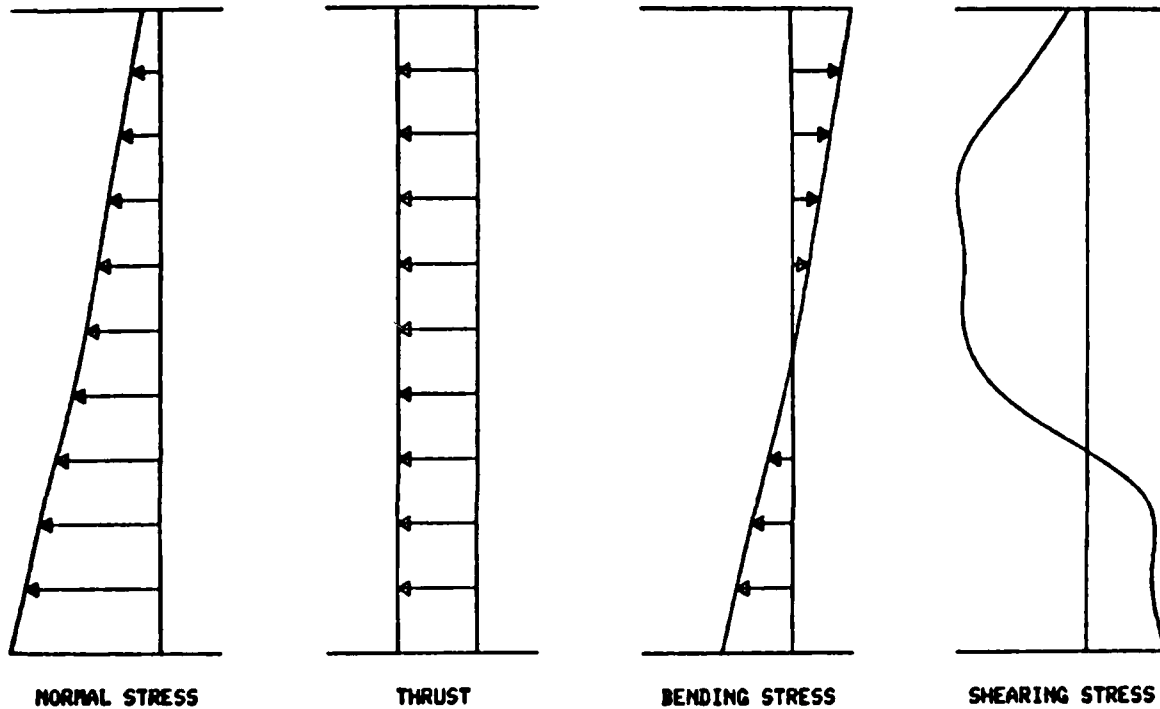
Figure A45. Load case 2B (section 17)





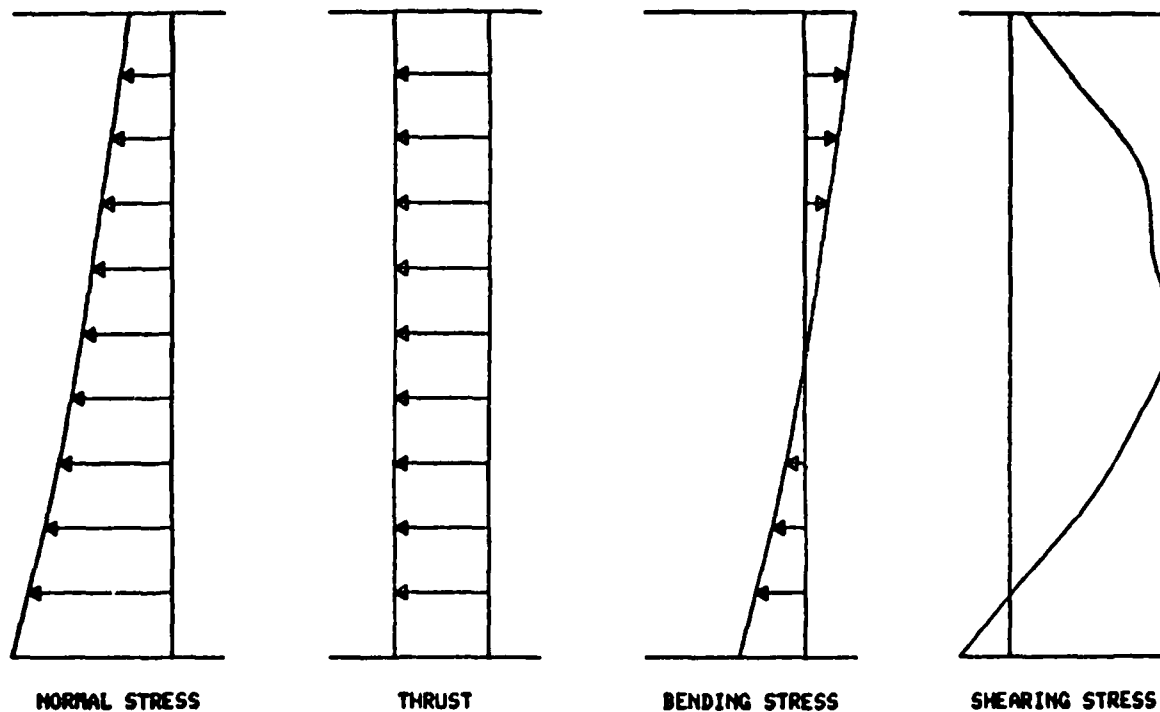
(X1, Y1) = (0., -1.)  
 (X2, Y2) = (0., 13.)  
 NEUTRAL AXIS = (0., 6.)  
 SHEAR = -.0005  
 MOMENT = -12.13  
 THRUST = -.0002

Figure A46. Load case 2B (section 18)



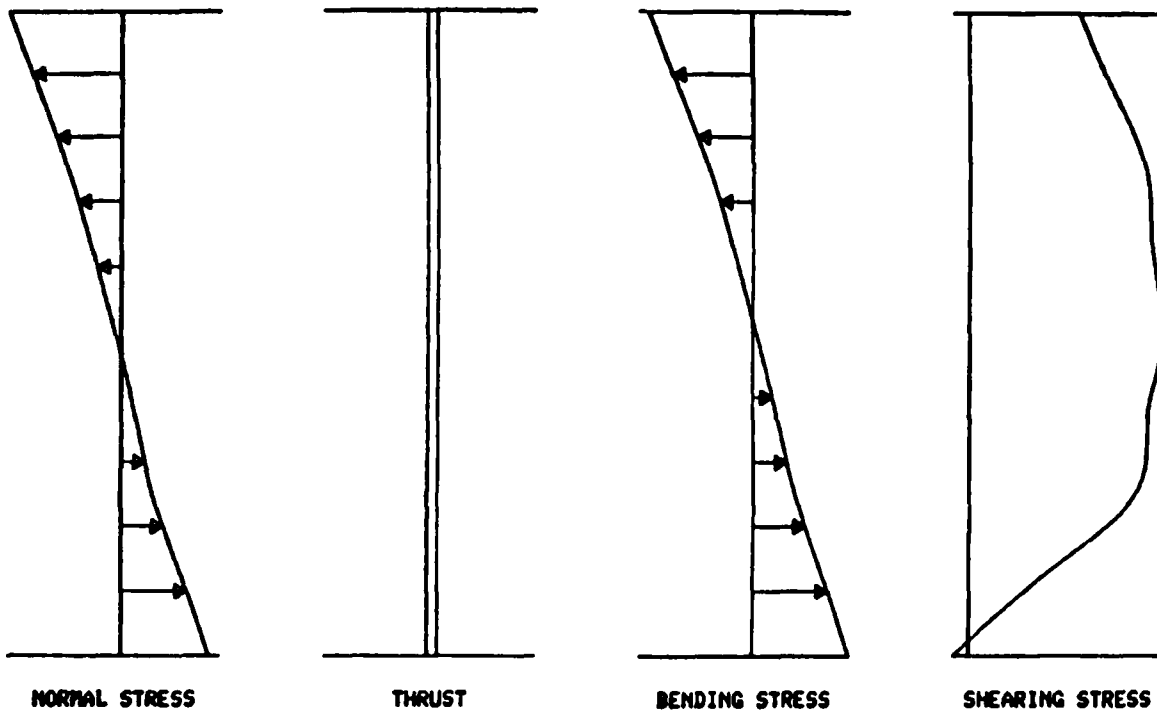
(X1, Y1) = (62.11.)  
 (X2, Y2) = (70.11.)  
 NEUTRAL AXIS = (65.86, 11.)  
 SHEAR = -.0096  
 MOMENT = -.1551  
 THRUST = -.278

Figure A47. Load case 2B (section 1A)



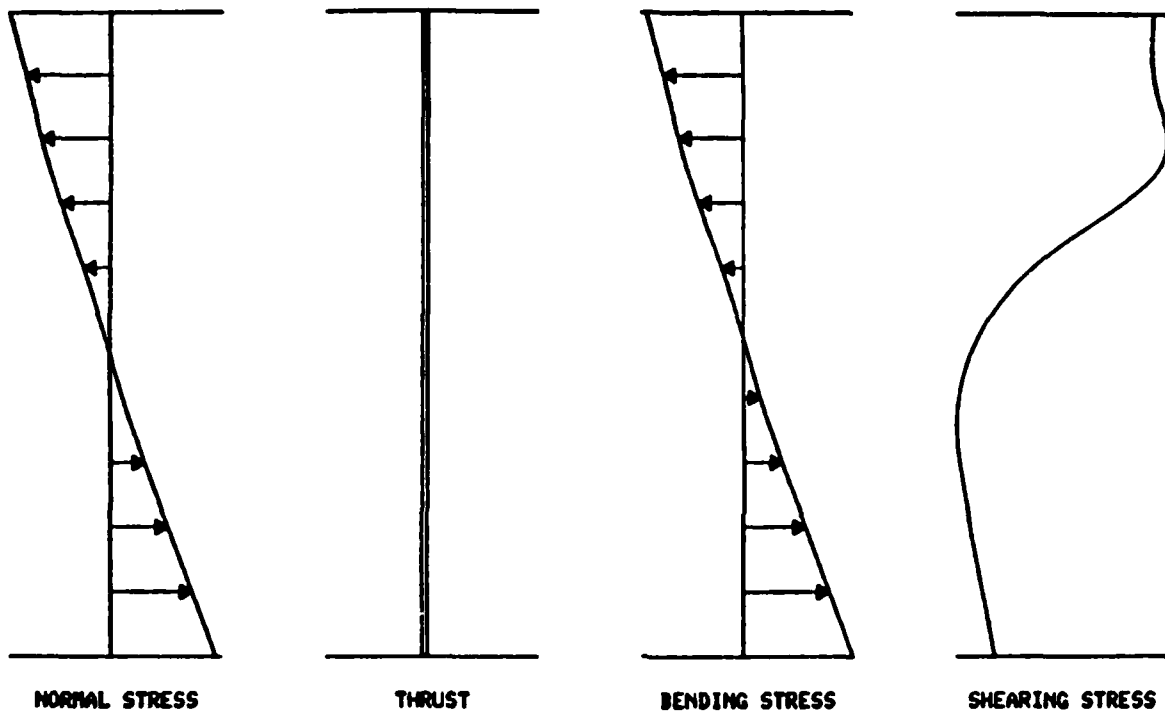
(X1, Y1) = (62., 21.)  
 (X2, Y2) = (70., 21.)  
 NEUTRAL AXIS = (65.84, 21.)  
 SHEAR = .028  
 MOMENT = -.0952  
 THRUST = -.2363

Figure A48. Load case 2B (section 2A)



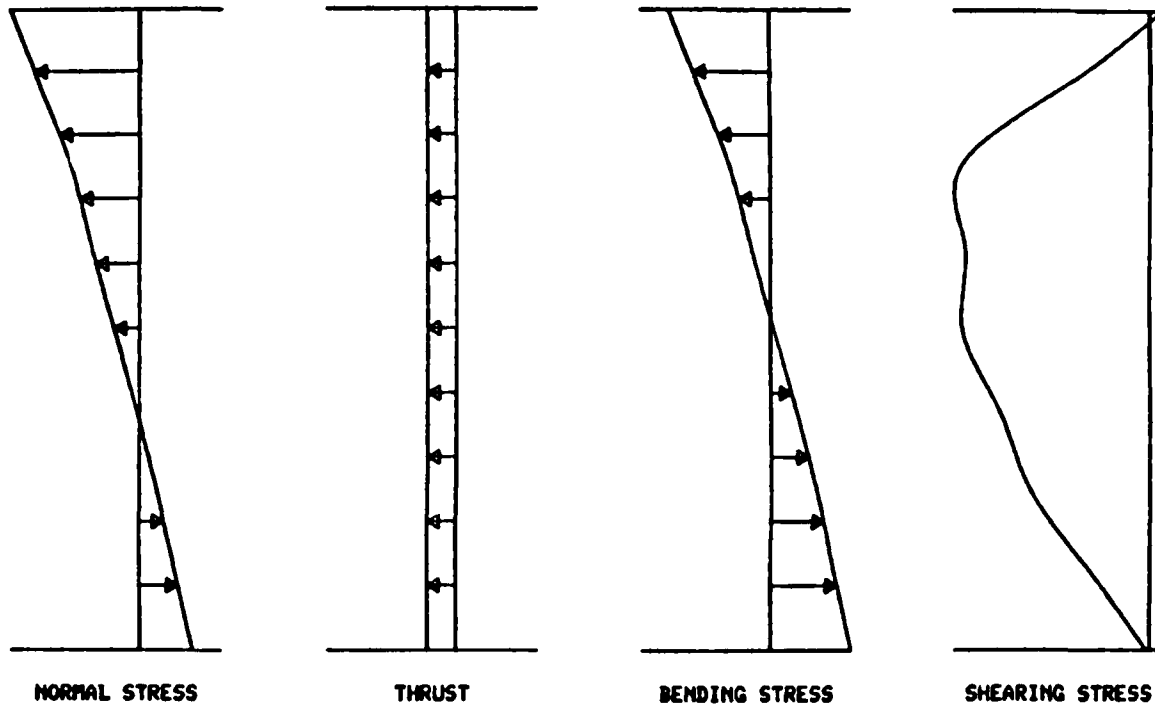
(X1, Y1) = (63., 20.)  
 (X2, Y2) = (63., 30.)  
 NEUTRAL AXIS = (63., 25.77)  
 SHEAR = .1493  
 MOMENT = .4667  
 THRUST = -.0406

Figure A49. Load case 2B (section 3A)



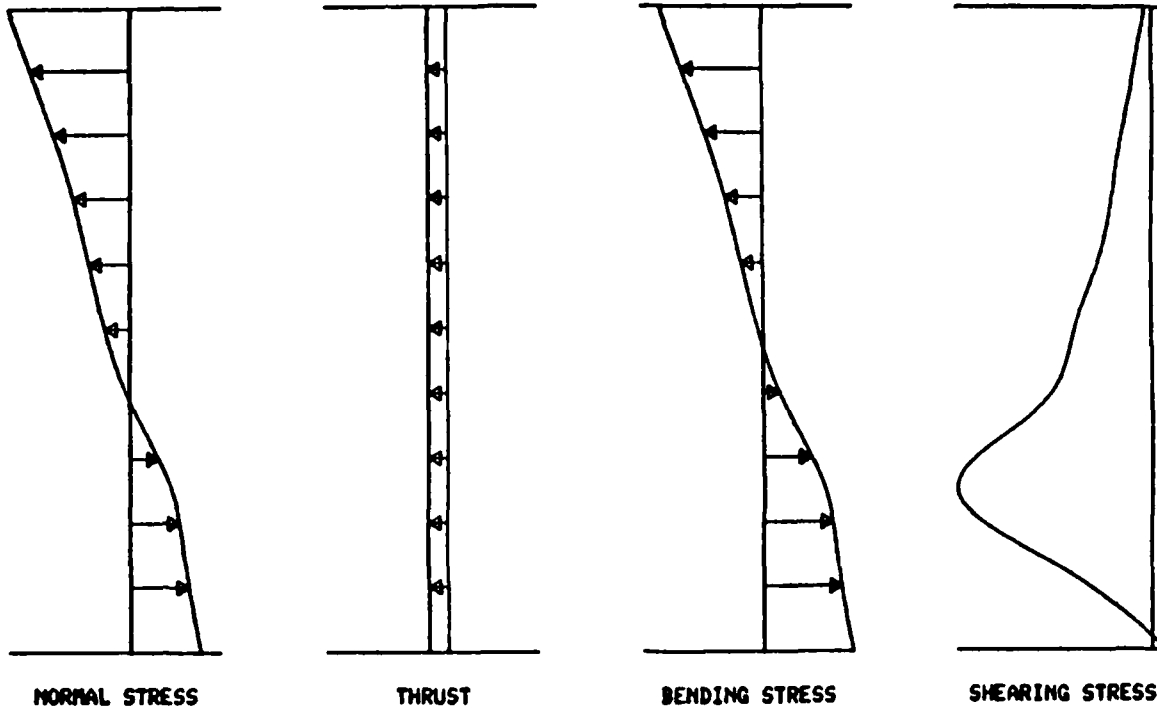
(X1, Y1) = (54.29)  
 (X2, Y2) = (54.33)  
 NEUTRAL AXIS = (54.2669)  
 SHEAR = .1213  
 MOMENT = 1.61  
 THRUST = -.0484

Figure A50. Load case 2B (section 4A)



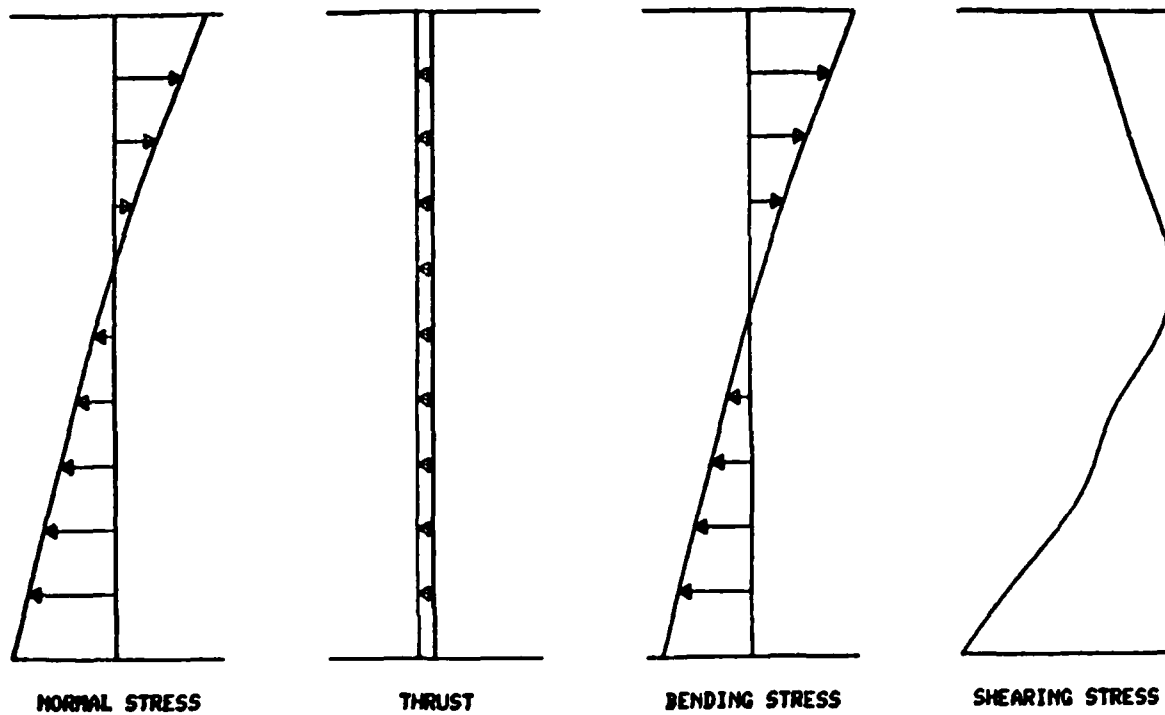
(X1, Y1) = (40, .20 )  
 (X2, Y2) = (54, .20 )  
 NEUTRAL AXIS = (47.2, .20 )  
 SHEAR = - 2684  
 MOMENT = 1 553  
 THRUST = - 2977

Figure A51. Load case 2B (section 5A)



(X1, Y1) = (40.,14.)  
 (X2, Y2) = (54.,14.)  
 NEUTRAL AXIS = (46.75,14.)  
 SHEAR = -.2886  
 MOMENT = 3.137  
 THRUST = -.3522

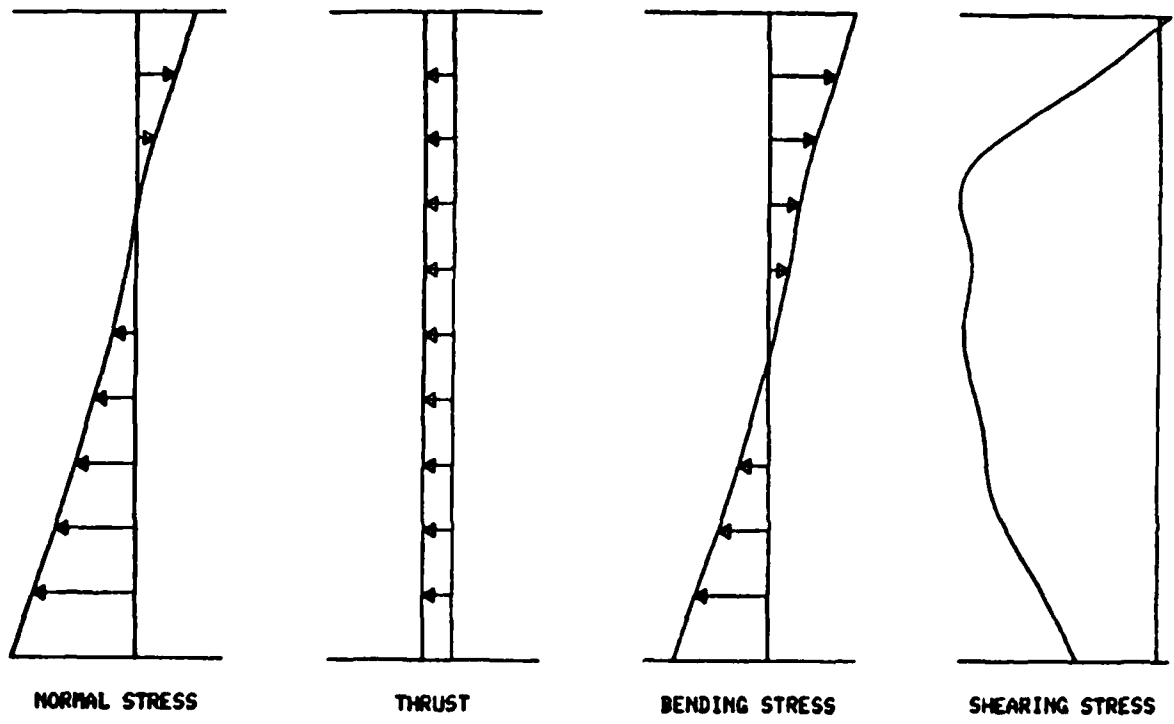
Figure A52. Load case 2B (section 6A)



(X1, Y1) = (54., 1.)  
 (X2, Y2) = (54., 11.)  
 NEUTRAL AXIS = (54., 6.367)  
 SHEAR = -.0832  
 MOMENT = -1.396  
 THRUST = -.177

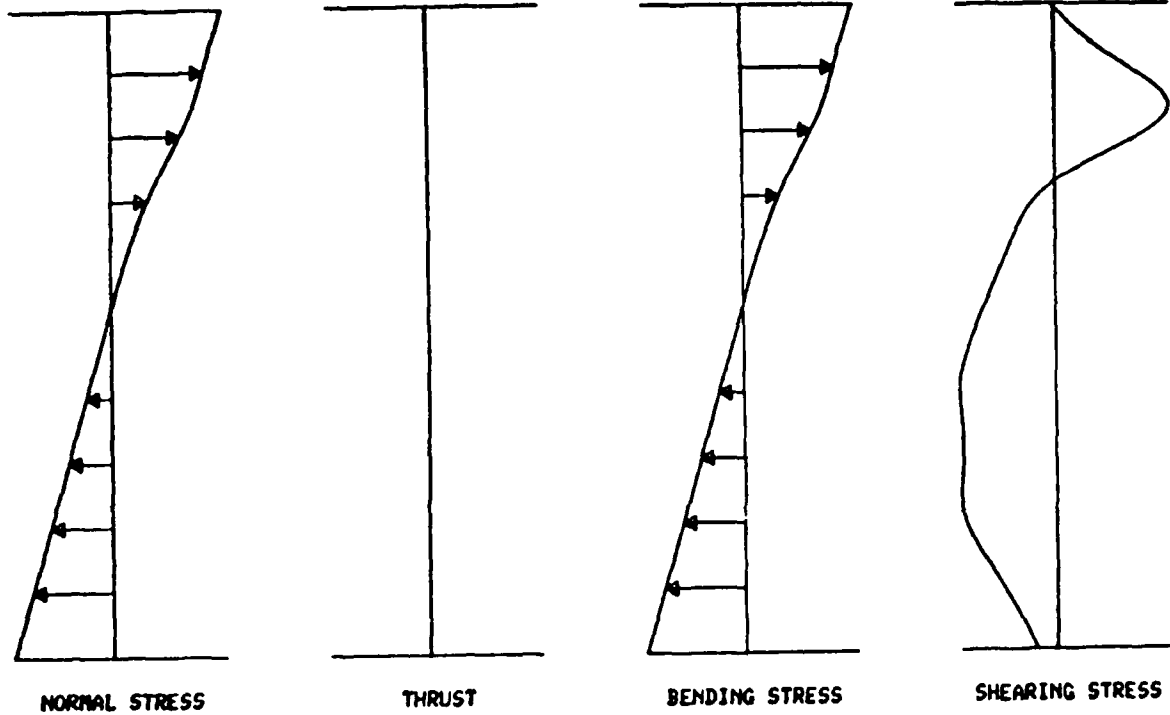
Figure A53. Load case 2B (section 7A)





(X1, Y1) • (63.3)  
 (X2, Y2) • (63.11)  
 NEUTRAL AXIS • (63.6.816)  
 SHEAR • - .1528  
 MOMENT • - .3612  
 THRUST • - .123

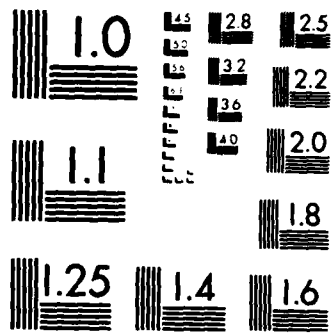
Figure A54. Load case 2B (section 8A)



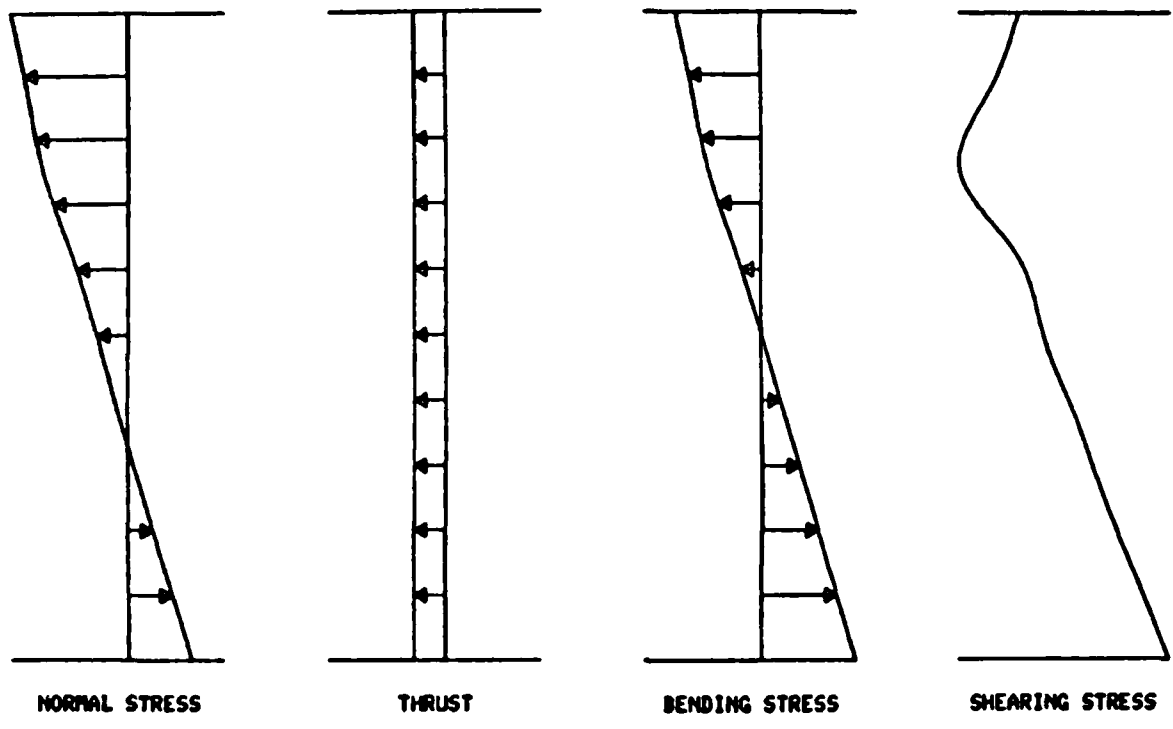
(X1, Y1) = (40., -1.)  
 (X2, Y2) = (40., 13.)  
 NEUTRAL AXIS = (40., 6.432)  
 SHEAR = -.1654  
 MOMENT = -8.542  
 THRUST = -.0024

Figure A55. Load case 2B (section 9A)





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NORMAL STRESS

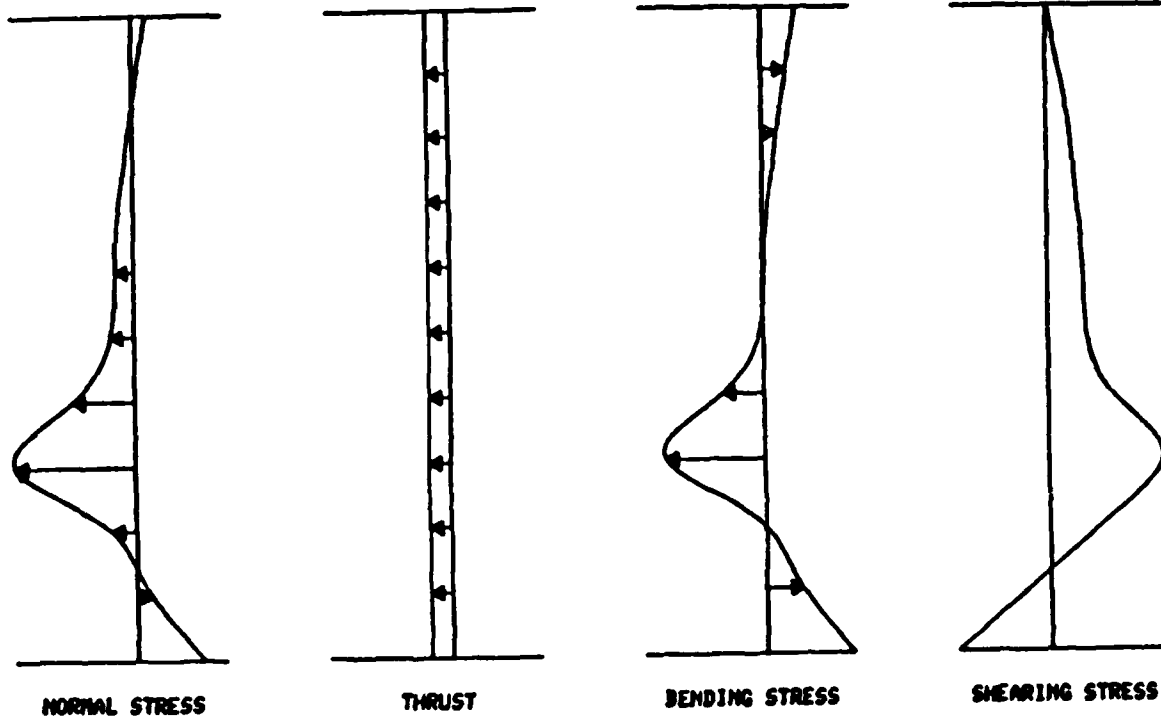
THRUST

BENDING STRESS

SHEARING STRESS

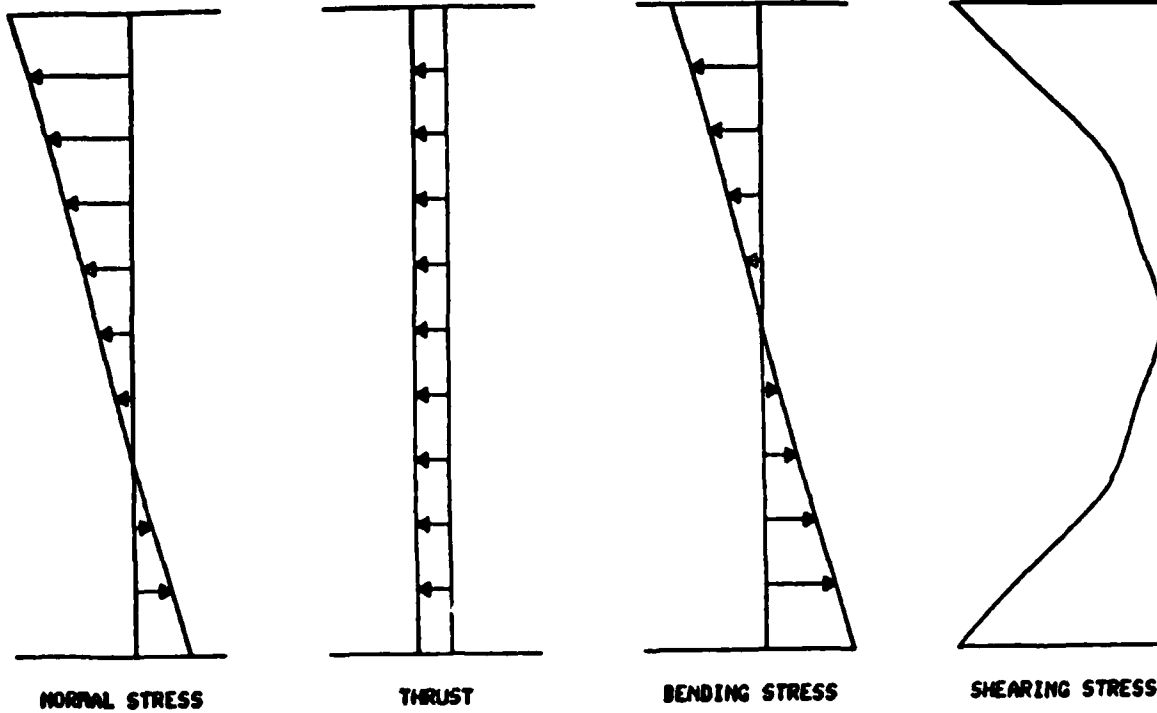
(X1, Y1) = (40, 36.)  
 (X2, Y2) = (52, 36.)  
 NEUTRAL AXIS = (46 55.36.)  
 SHEAR = - 1335  
 MOMENT = 1.112  
 THRUST = - 2476

Figure A56. Load case 2B (section 10A)



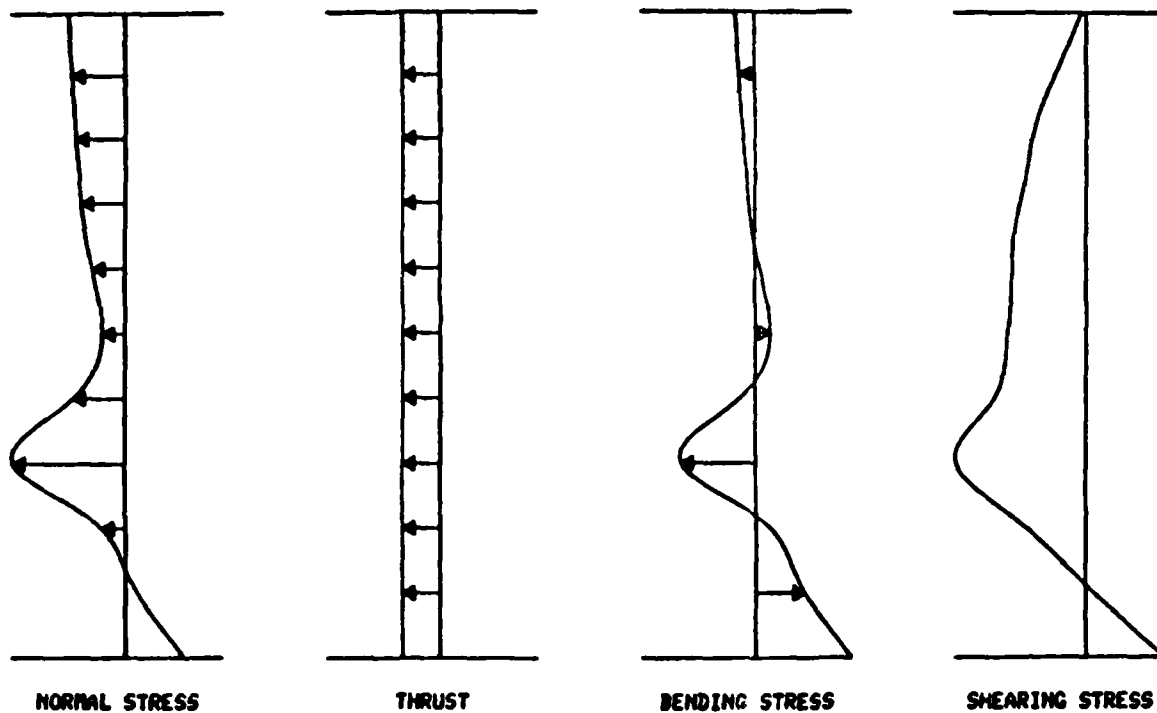
(X1, Y1) = (62.10.)  
 (X2, Y2) = (70.10.)  
 NEUTRAL AXIS = (65.4.10.)  
 SHEAR = .1567  
 MOMENT = -.0675  
 THRUST = -.1845

Figure A57. Load case 5A (section 1)



(X1, Y1) = (62 .16.)  
 (X2, Y2) = (70 .16.)  
 NEUTRAL AXIS = (66 .16.)  
 SHEAR = .0158  
 MOMENT = .2491  
 THRUST = -.1456

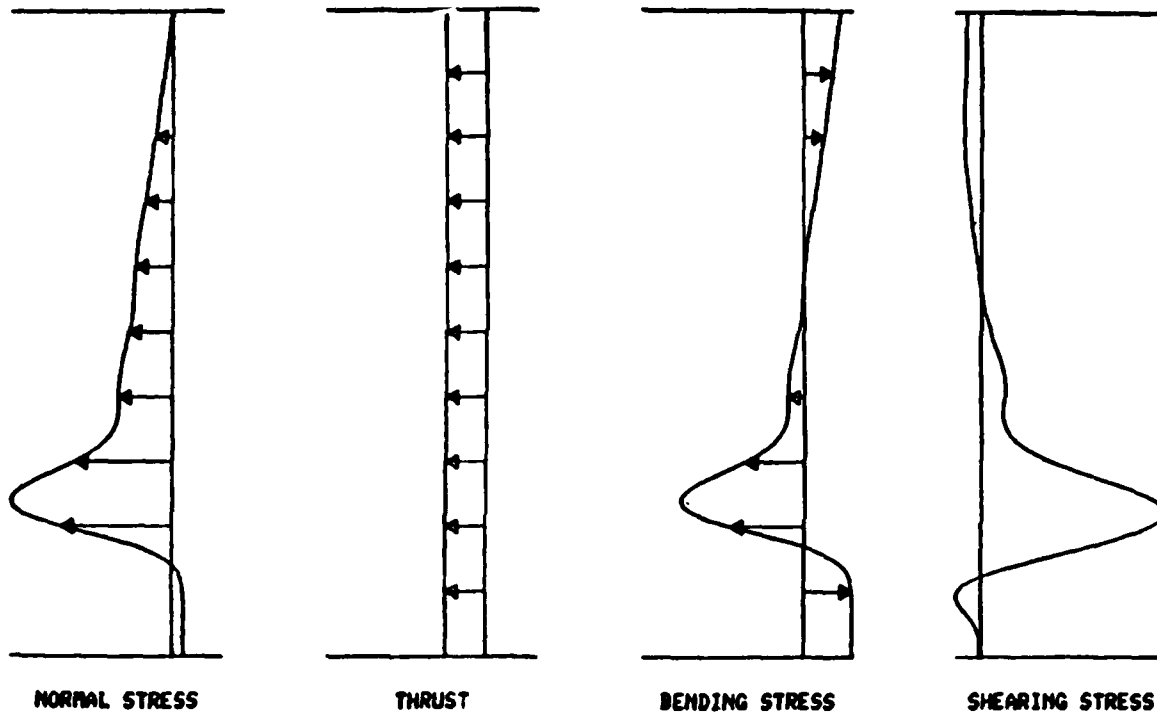
Figure A58. Load case 5A (section 2)



(X1, Y1) • (62 ,22.)  
 (X2, Y2) • (70 ,22.)  
 NEUTRAL AXIS • (65 91.22.)  
 SHEAR • -.1093  
 MOMENT • .0896  
 THRUST • -.1277

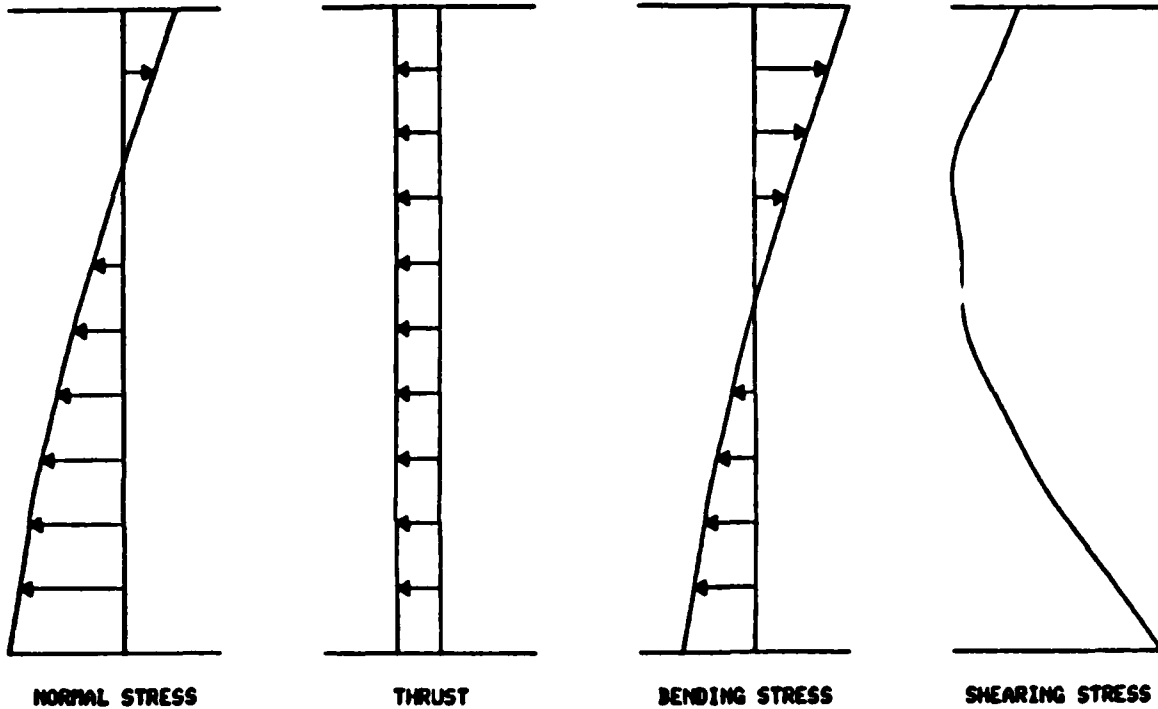
Figure A59. Load case 5A (section 3)





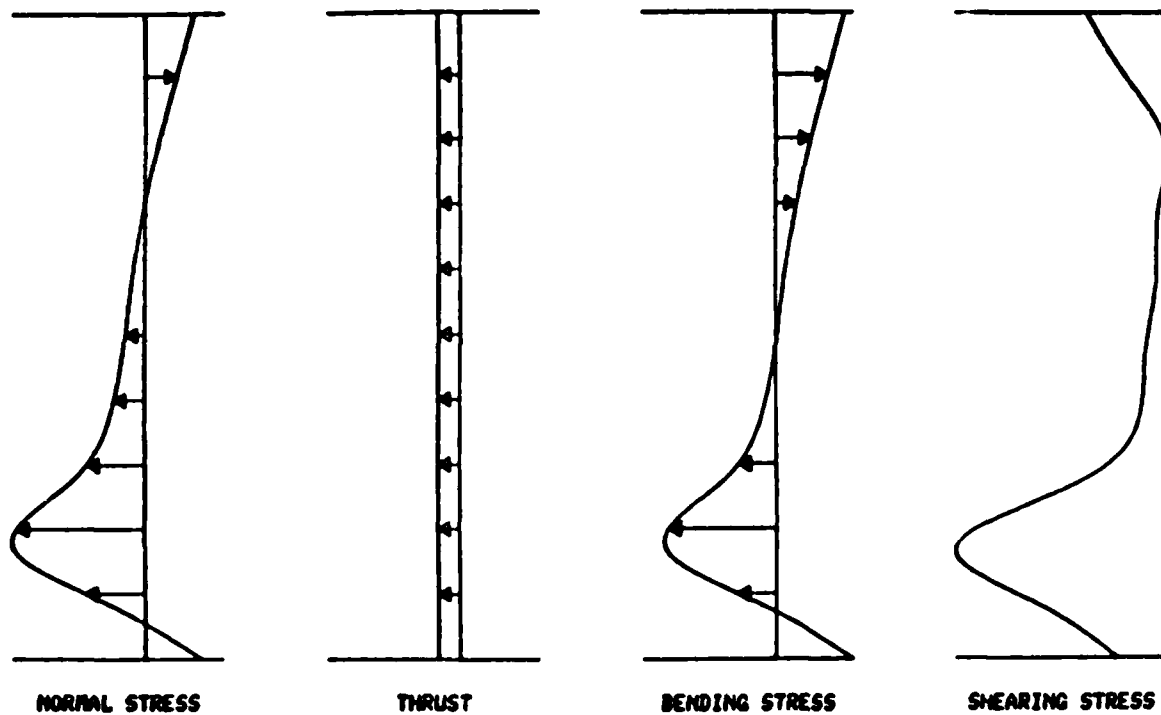
(X1, Y1) = (64 .20.)  
 (X2, Y2) = (64 .30.)  
 NEUTRAL AXIS = (64 .25.28)  
 SHEAR = .0472  
 MOMENT = -.1636  
 THRUST = -.22

Figure A60. Load case 5A (section 4)



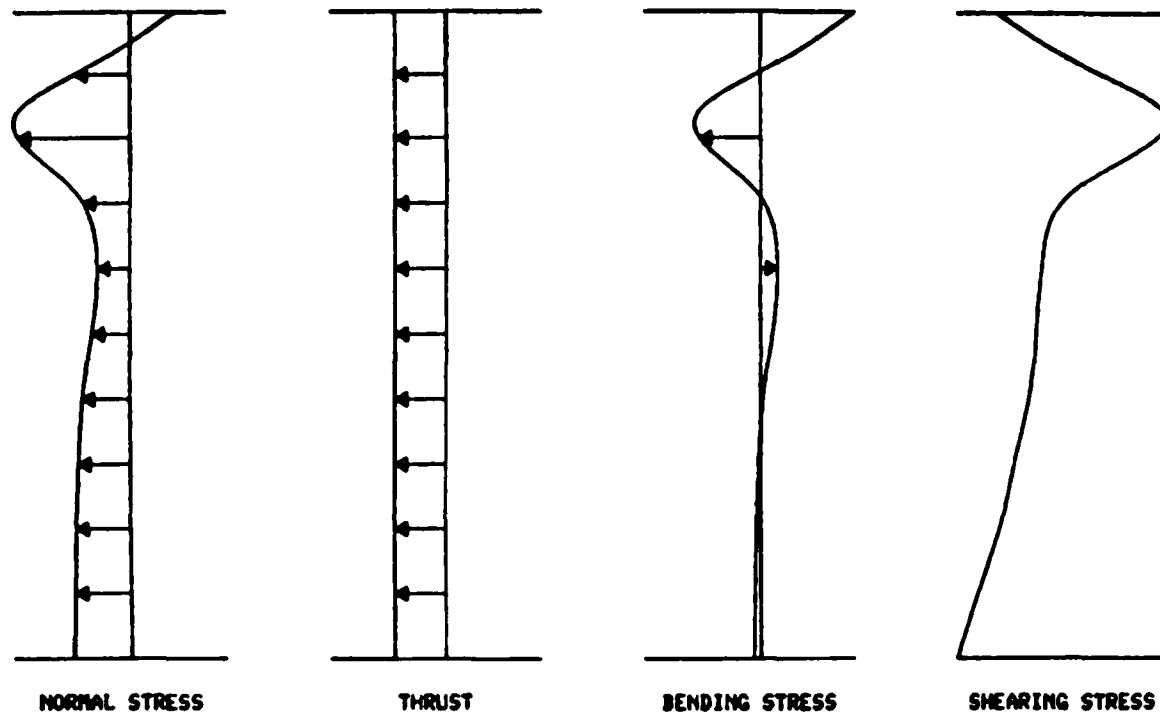
(X1, Y1) • (58 .20 )  
 (X2, Y2) • (58 .32 )  
 NEUTRAL AXIS • (58 .26.56)  
 SHEAR • - .1043  
 MOMENT • - .628  
 THRUST • - .2237

Figure A61. Load case 5A (section 5)



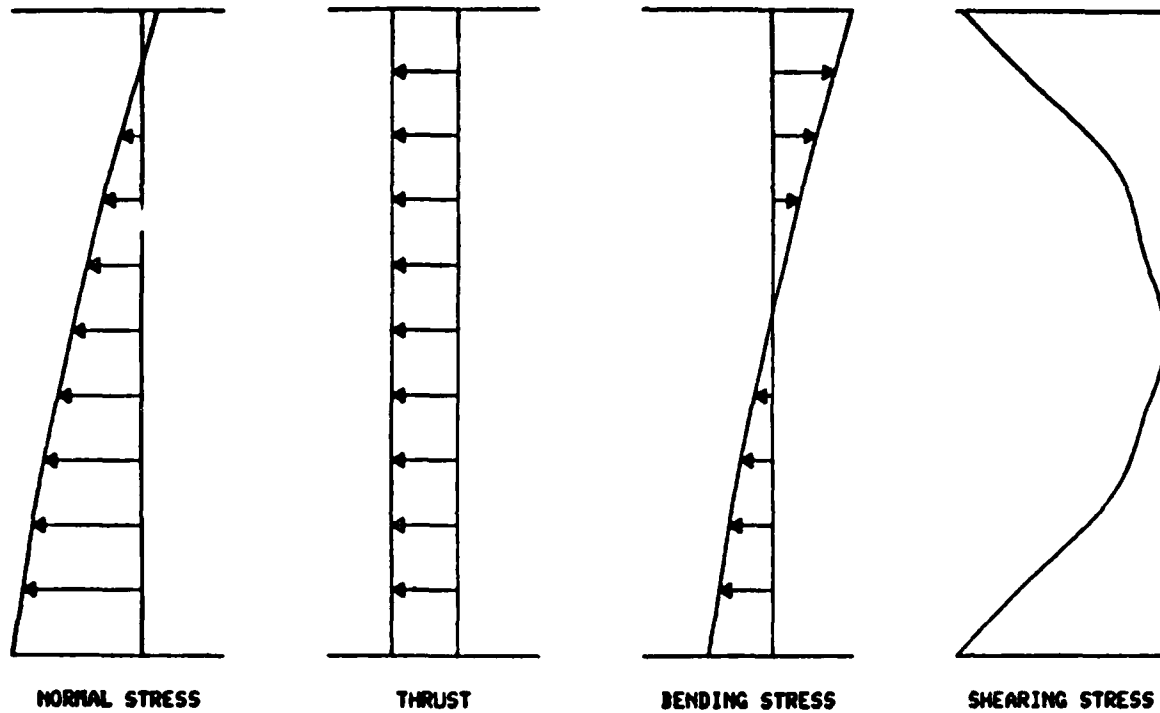
(X1, Y1) • (52 .20 )  
 (X2, Y2) • (52 .33 )  
 NEUTRAL AXIS • (52 .25.77)  
 SHEAR • - .2874  
 MOMENT • -1.63  
 THRUST • -.317

Figure A62. Load case 5A (section 6)



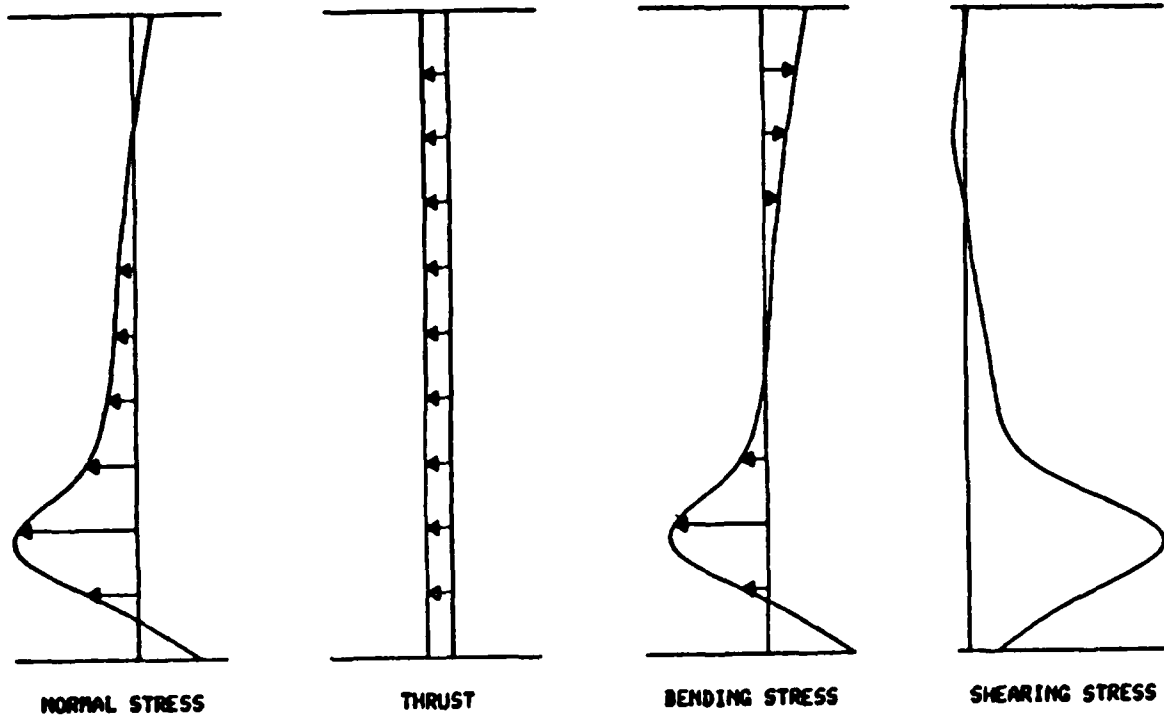
(X1, Y1) = (40, 22.)  
 (X2, Y2) = (54, 22.)  
 NEUTRAL AXIS = (52, 81, 22.)  
 SHEAR = .3724  
 MOMENT = -.1478  
 THRUST = -.7049

Figure A63. Load case 5A (section 7)



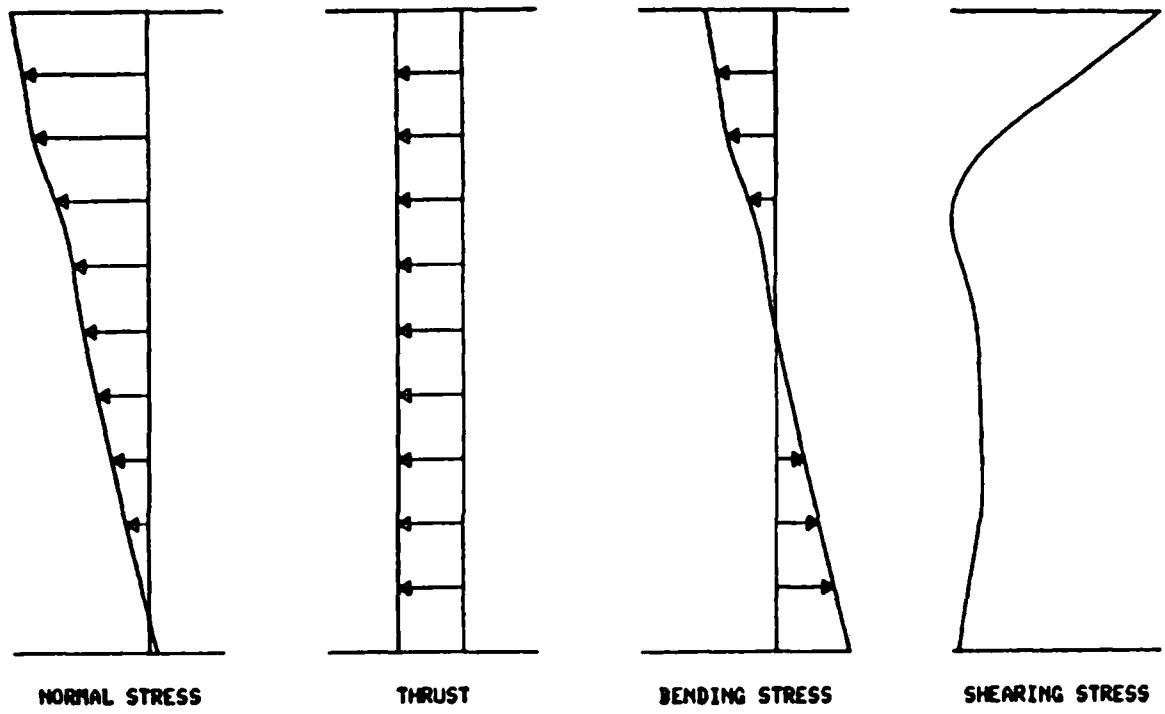
(X1, Y1) = (40 .17.)  
 (X2, Y2) = (54 .17.)  
 NEUTRAL AXIS = (47 26.17.)  
 SHEAR = .3265  
 MOMENT = -1.323  
 THRUST = -.7197

Figure A64. Load case 5A (section 8)



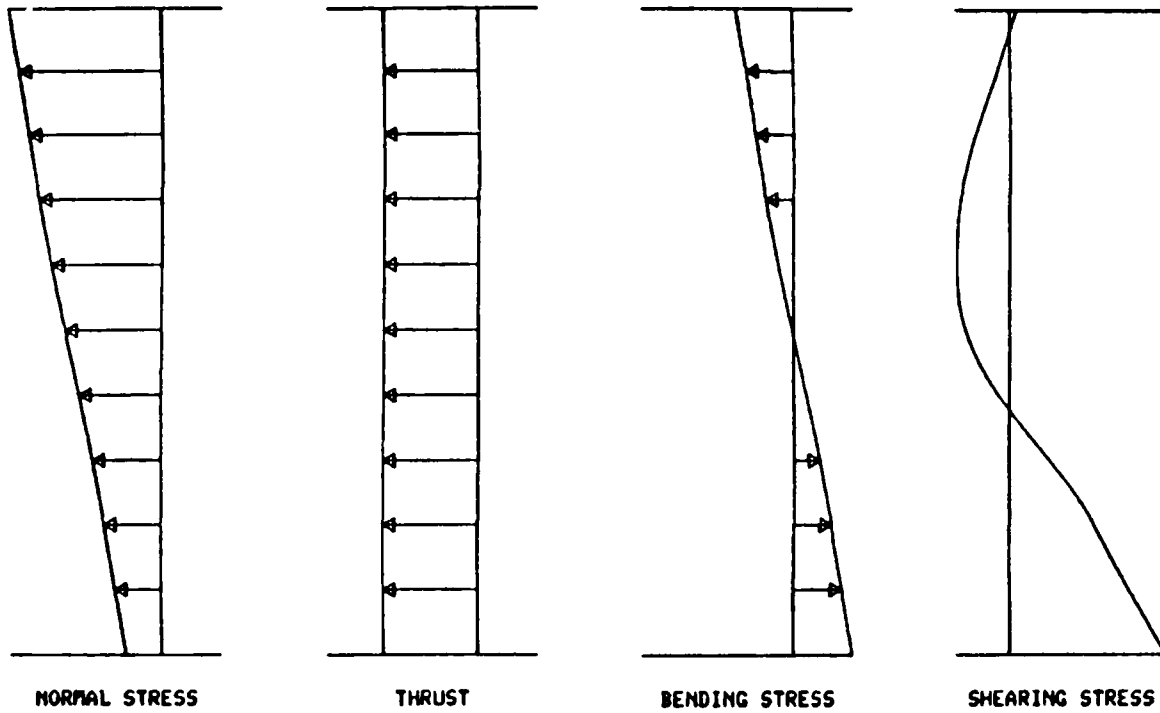
(X1, Y1) = (40 .12.)  
 (X2, Y2) = (54 .12.)  
 NEUTRAL AXIS = (45 36.12.)  
 SHEAR = .4446  
 MOMENT = -2.444  
 THRUST = -.8664

Figure A65. Load case 5A (section 9)



(X1, Y1) • (52 .1 )  
 (X2, Y2) • (52 .11 )  
 NEUTRAL AXIS • (52 .6 S18)  
 SHEAR • .1377  
 MOMENT • .7629  
 THRUST • -.4541

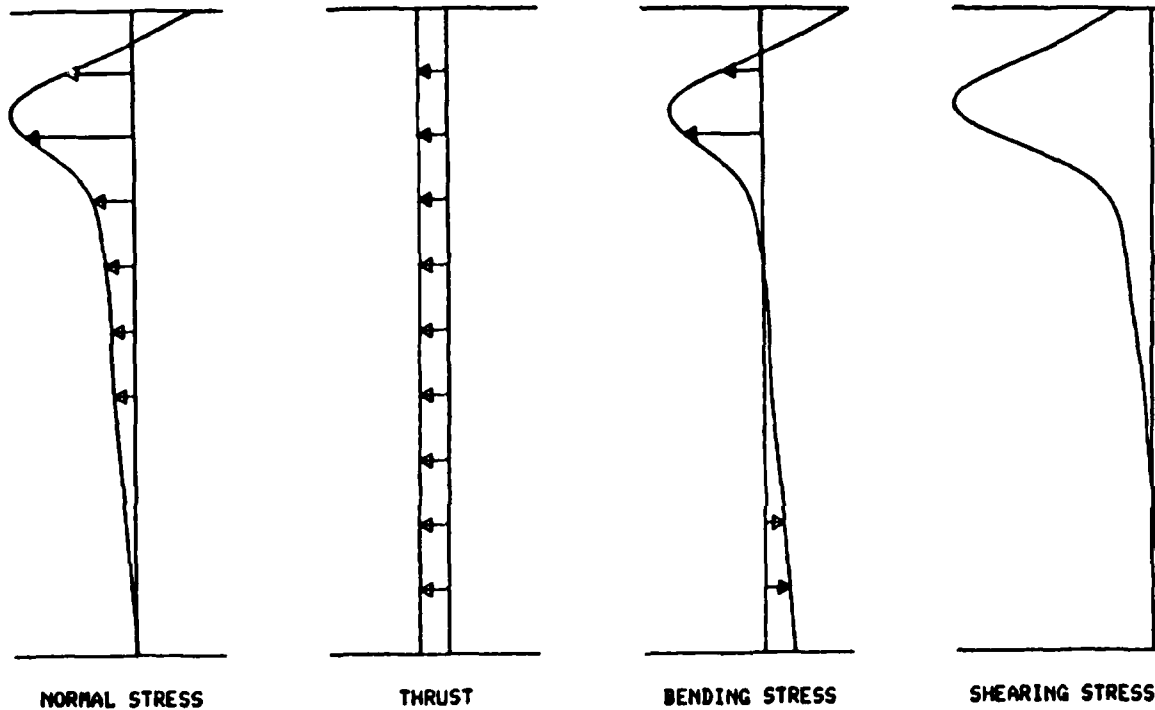
Figure A66. Load case 5A (section 10)



(X1, Y1) = (58 .2 )  
 (X2, Y2) = (58 .11 )  
 NEUTRAL AXIS = (58 .6.486)  
 SHEAR = .0012  
 MOMENT = .2525  
 THRUST = -.3404

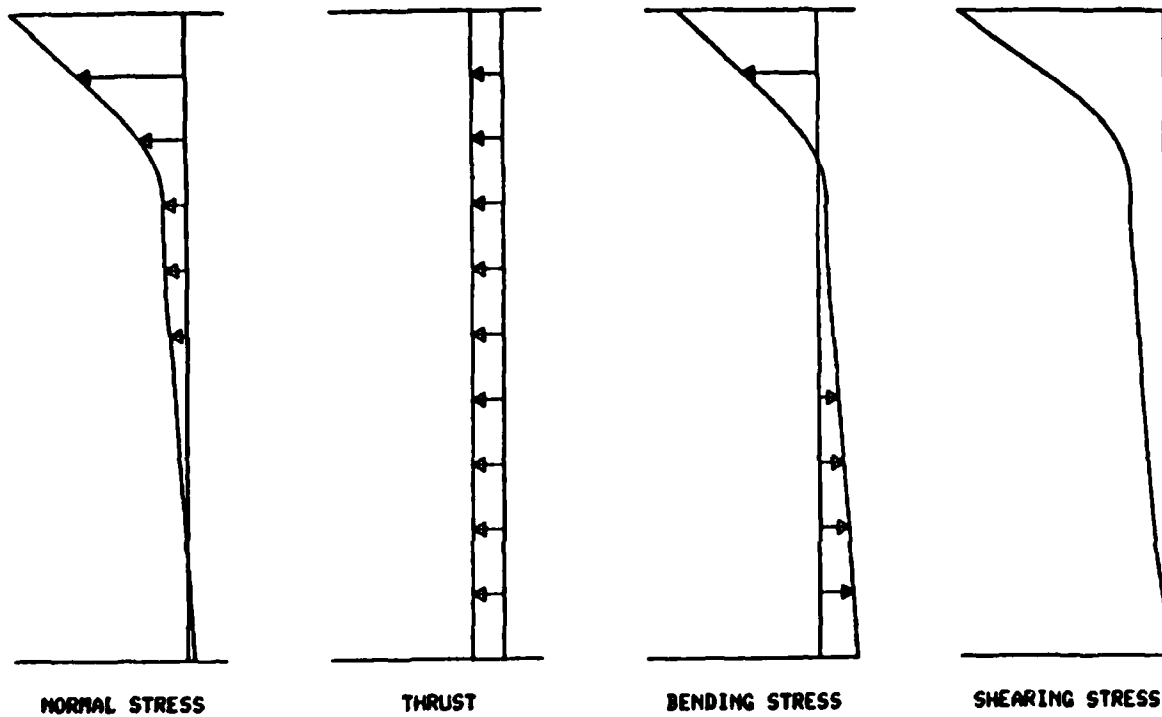
Figure A67. Load case 5A (section 11)





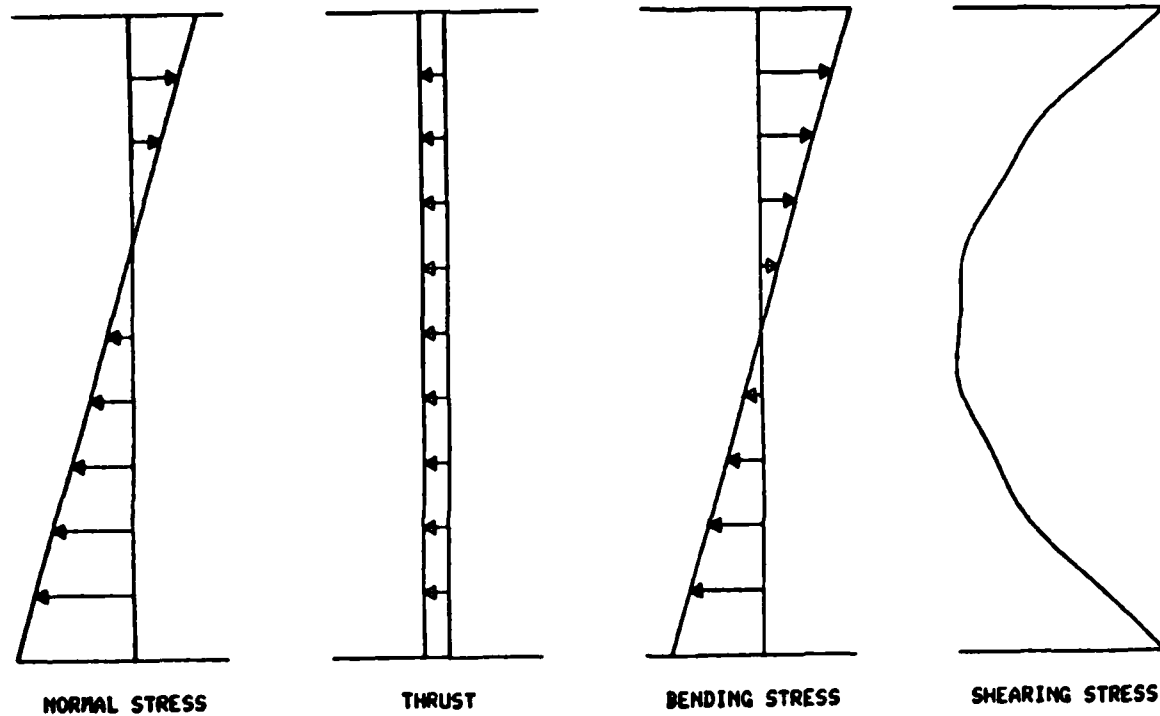
(X1, Y1) = (64 .3 )  
 (X2, Y2) = (64 .11.)  
 NEUTRAL AXIS = (64 .10.5)  
 SHEAR = - 1437  
 MOMENT = 3856  
 THRUST = - 3402

Figure A68. Load case 5A (section 12)



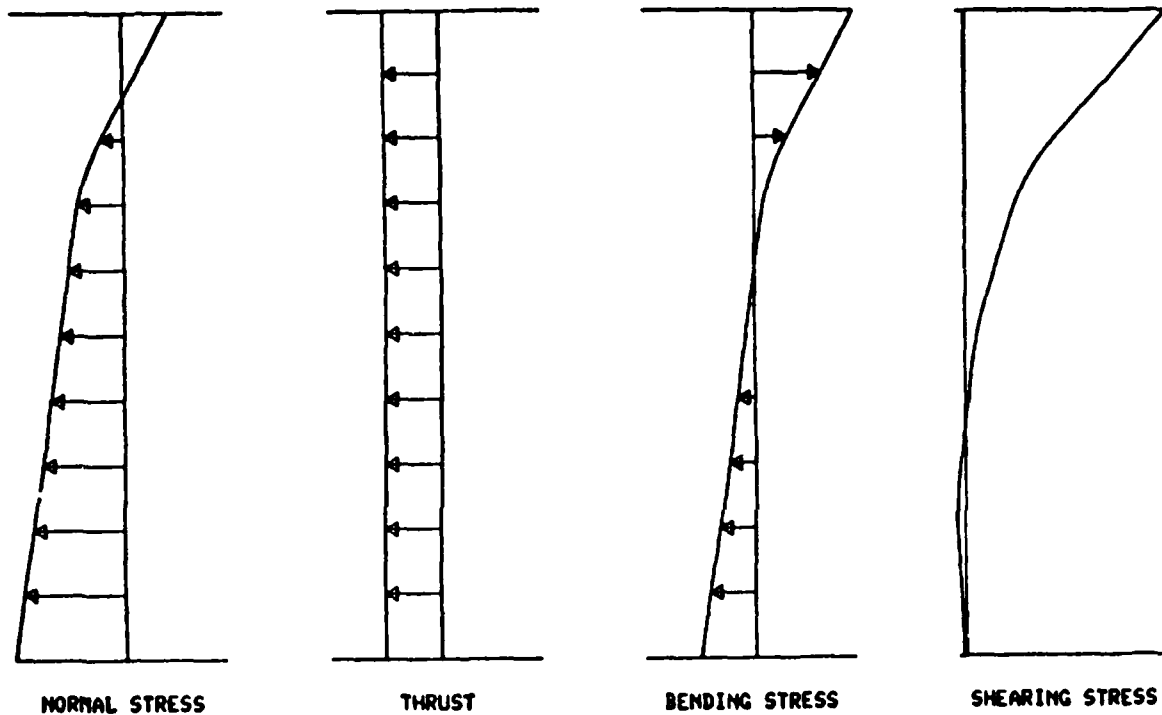
(X1, Y1) = (42, -1 )  
 (X2, Y2) = (42, .13 )  
 NEUTRAL AXIS = (42, 9.772)  
 SHEAR = -.655  
 MOMENT = 4.574  
 THRUST = -1.066

Figure A69. Load case 5A (section 13)



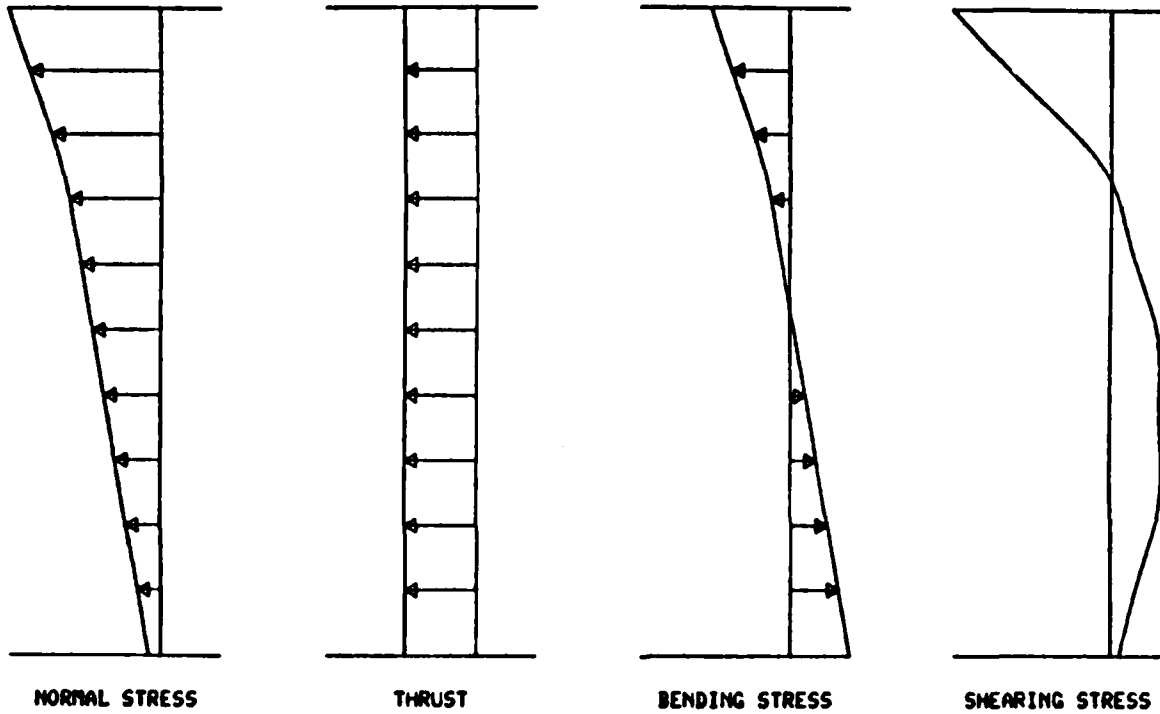
(X1, Y1) = (20, -1 )  
 (X2, Y2) = (20, 13 )  
 NEUTRAL AXIS = (20, 6.001)  
 SHEAR = - 2533  
 MOMENT = -5.444  
 THRUST = -.7476

Figure A70. Load case 5A (section 14)



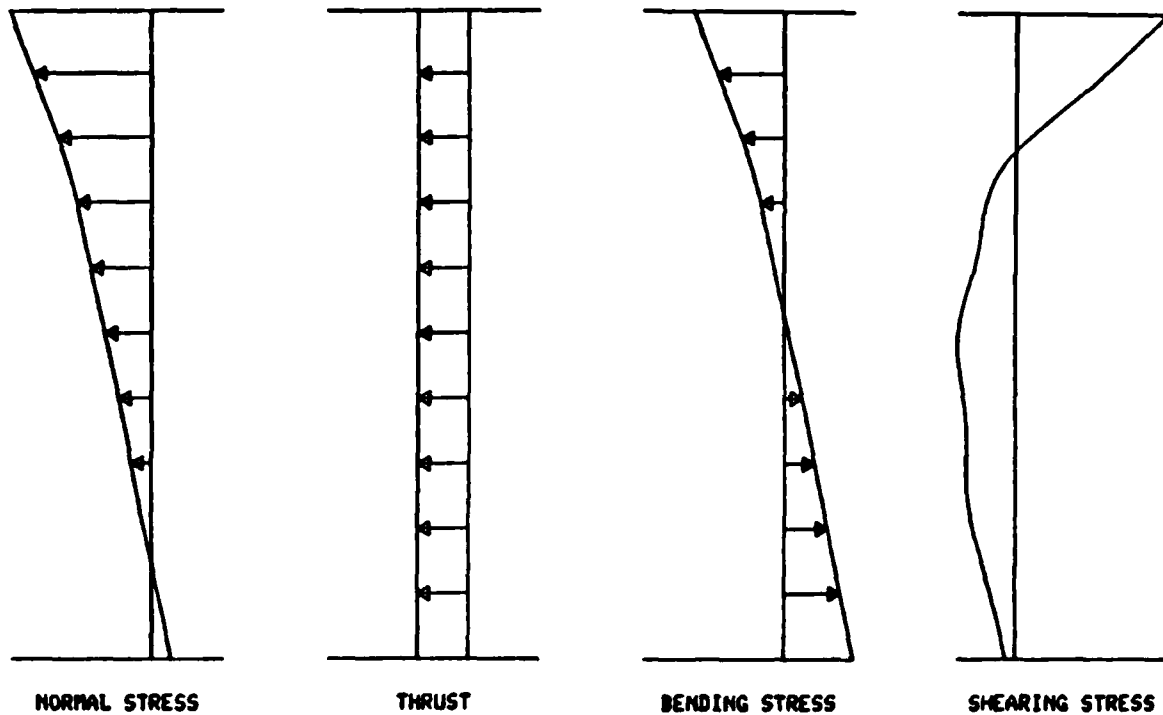
(X1, Y1) = (40 .32 )  
 (X2, Y2) = (53 .32 )  
 NEUTRAL AXIS = (48 01.32.)  
 SHEAR = .0628  
 MOMENT = - .636  
 THRUST = - .3185

Figure A71. Load case 5A (section 15)



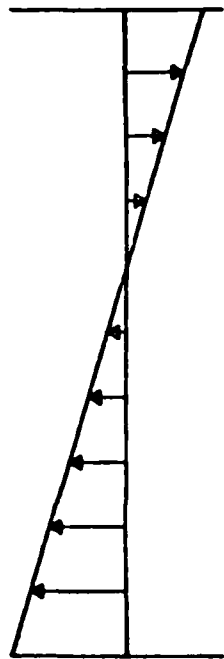
(X1, Y1) = (40 .53.)  
 (X2, Y2) = (48 .53.)  
 NEUTRAL AXIS = (44 67.53.)  
 SHEAR = .0006  
 MOMENT = .0877  
 THRUST = -.1158

Figure A72. Load case 5A (section 16)

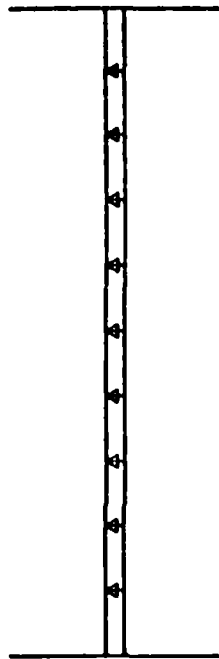


(X1, Y1) • (40 .63 )  
 (X2, Y2) • (48 .63 )  
 NEUTRAL AXIS • (44.65.63.)  
 SHEAR • -.0037  
 MOMENT • .0853  
 THRUST • -.0686

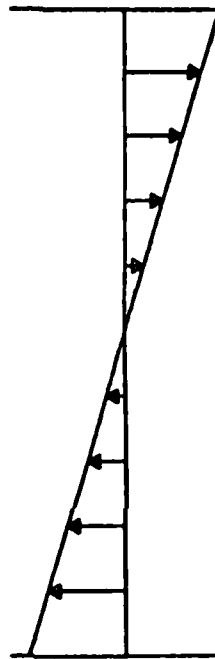
Figure A73. Load case 5A (section 17)



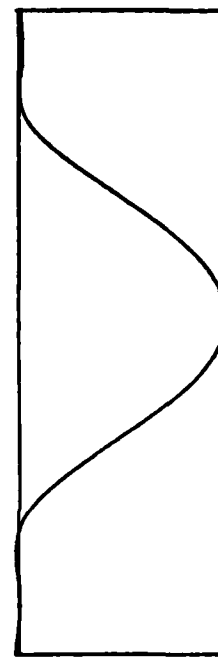
NORMAL STRESS



THRUST



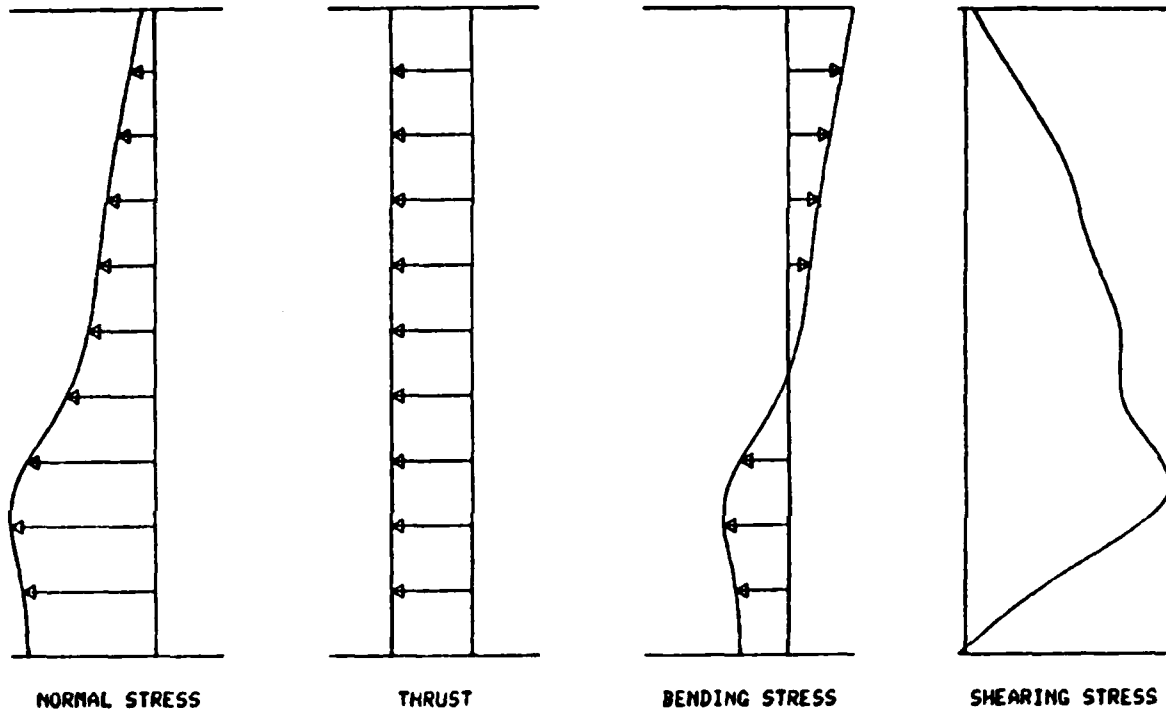
BENDING STRESS



SHEARING STRESS

(X1, Y1) = (0, -1 )  
 (X2, Y2) = (0, .13 )  
 NEUTRAL AXIS = (0, .6 001 )  
 SHEAR = 0088  
 MOMENT = -7.779  
 THRUST = -.7476

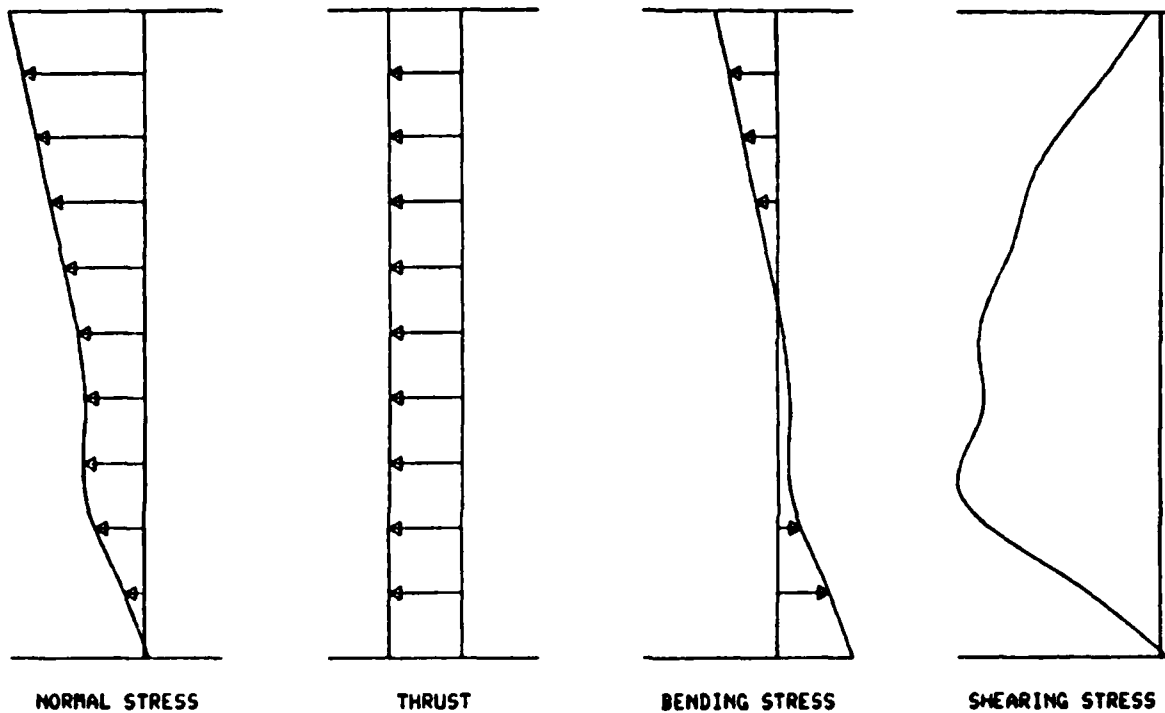
Figure A74. Load case 5A (section 18)



(X1, Y1) \* (62 .11 )  
 (X2, Y2) \* (70 .11 )  
 NEUTRAL AXIS \* (65 79.11 )  
 SHEAR \* 1339  
 MOMENT \* - 1029  
 THRUST \* - 1694

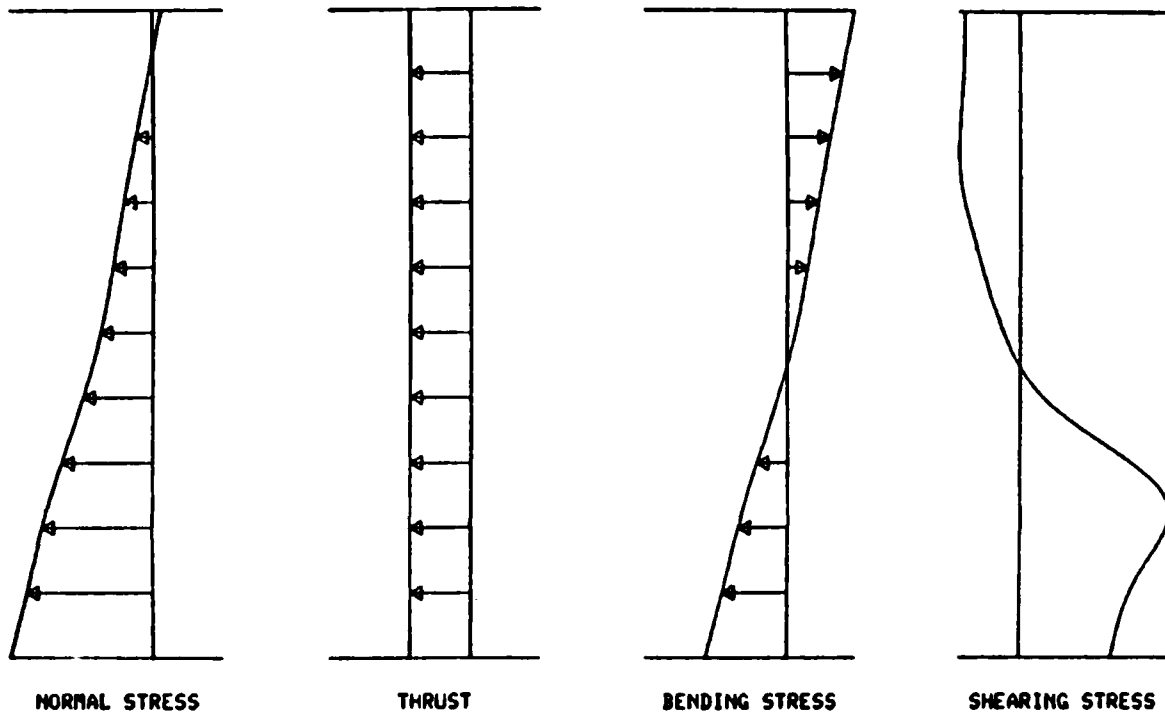
Figure A75. Load case 5A (section 1A)





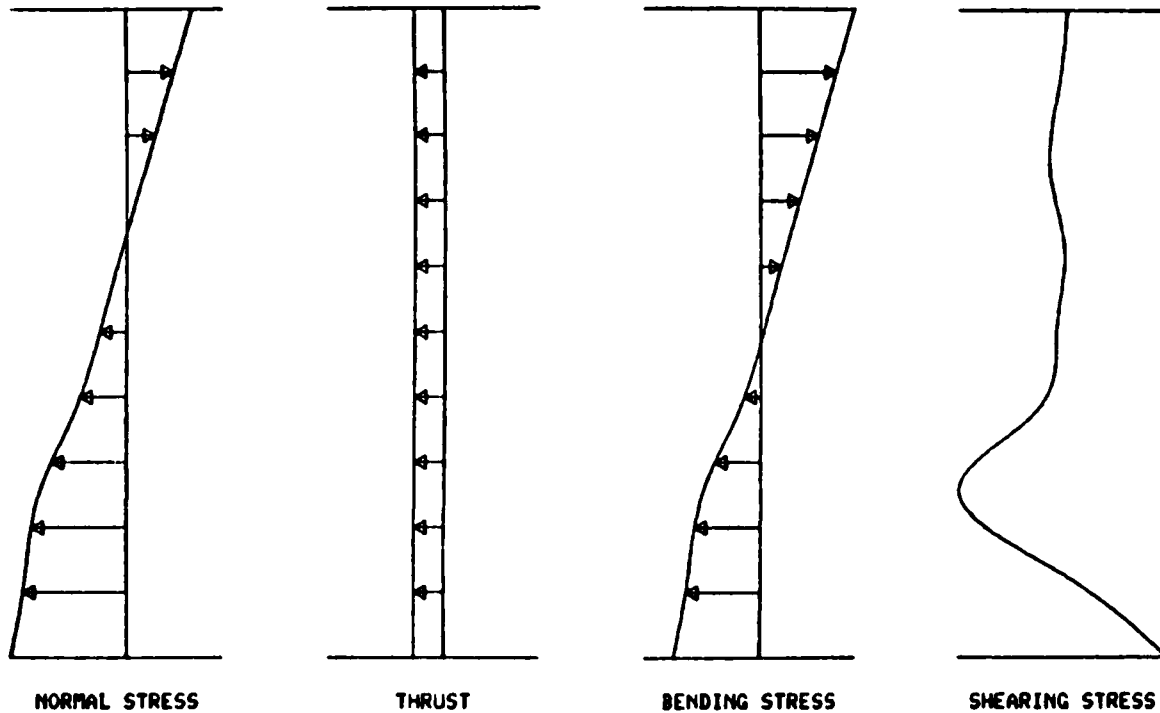
(X1, Y1) = (62 .21 )  
 (X2, Y2) = (70 .21 )  
 NEUTRAL AXIS = (66 16.21 )  
 SHEAR = - 0849  
 MOMENT = 0693  
 THRUST = - 1268

Figure A76. Load case 5A (section 2A)



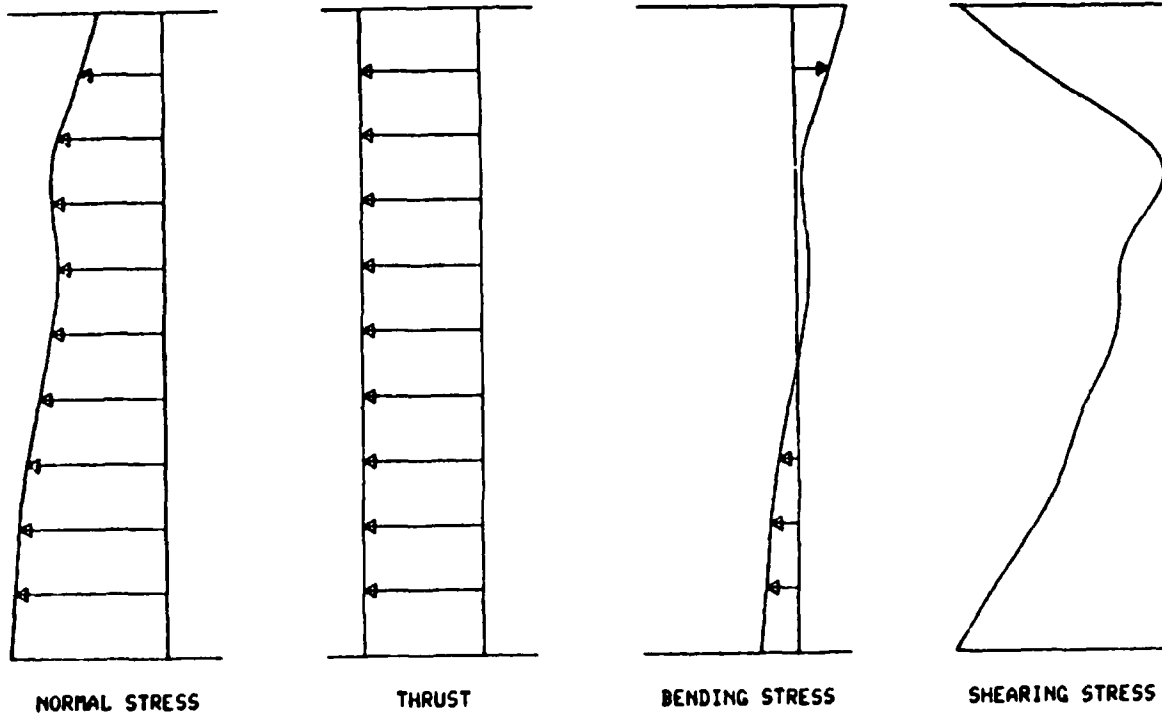
(X1, Y1) • (63 .20 )  
 (X2, Y2) • (63 .30 )  
 NEUTRAL AXIS • (63 .25 29)  
 SHEAR • .0187  
 MOMENT • - 3057  
 THRUST • - .2012

Figure A77. Load case 5A (section 3A)



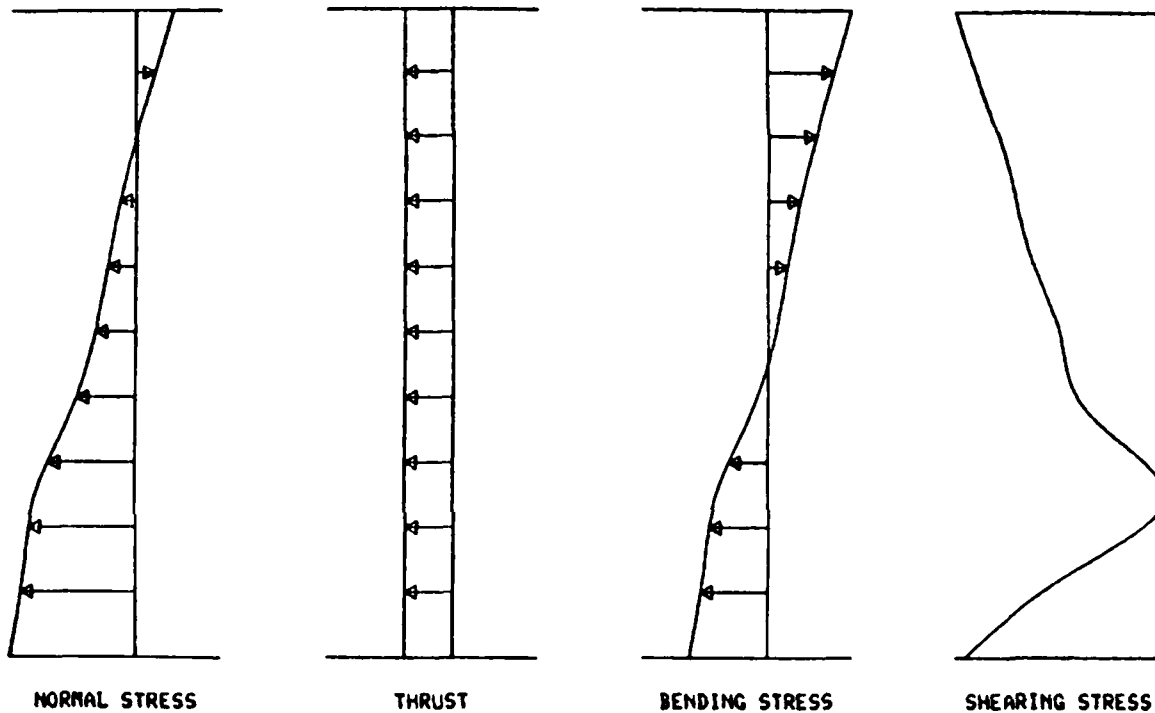
(X1, Y1) = (54 .20 )  
 (X2, Y2) = (54 .33 )  
 NEUTRAL AXIS = (54 .26 61)  
 SHEAR = - 204  
 MOMENT = -1 24  
 THRUST = - 2416

Figure A78. Load case 5A (section 4A)



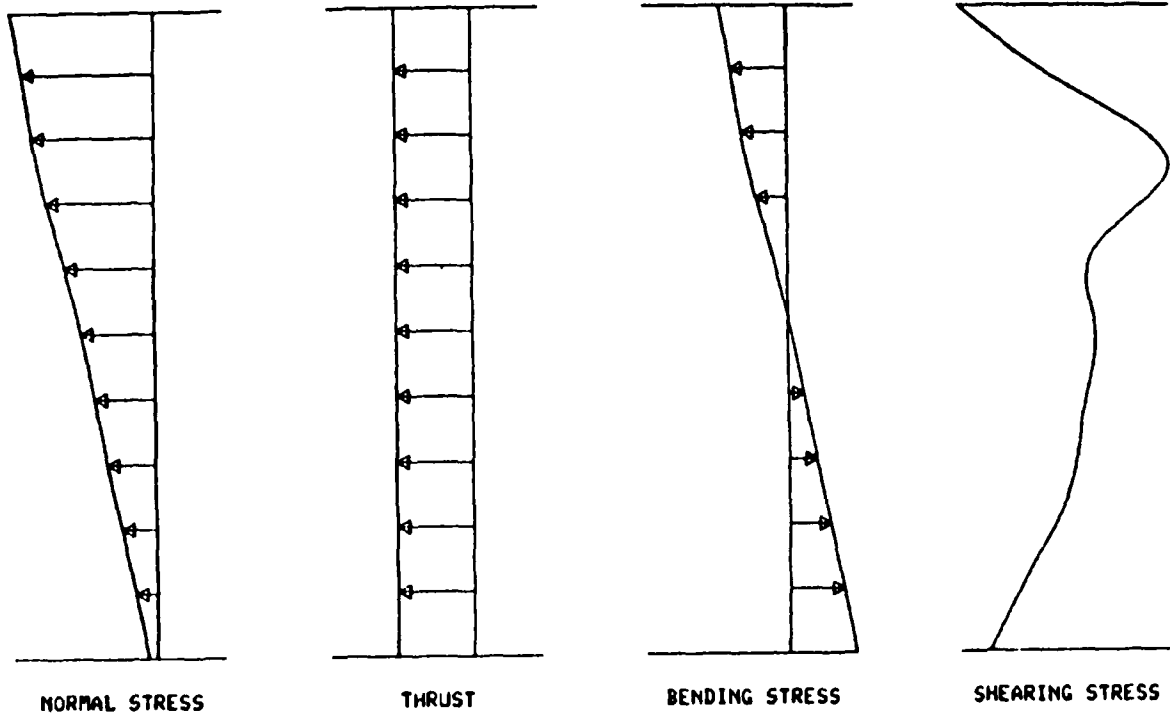
(X1, Y1) • (40 .20 )  
 (X2, Y2) • (54 .20 )  
 NEUTRAL AXIS • (46 49.20 )  
 SHEAR • 3266  
 MOMENT • - 3843  
 THRUST • - 6706

Figure A79. Load case 5A (section 5A)



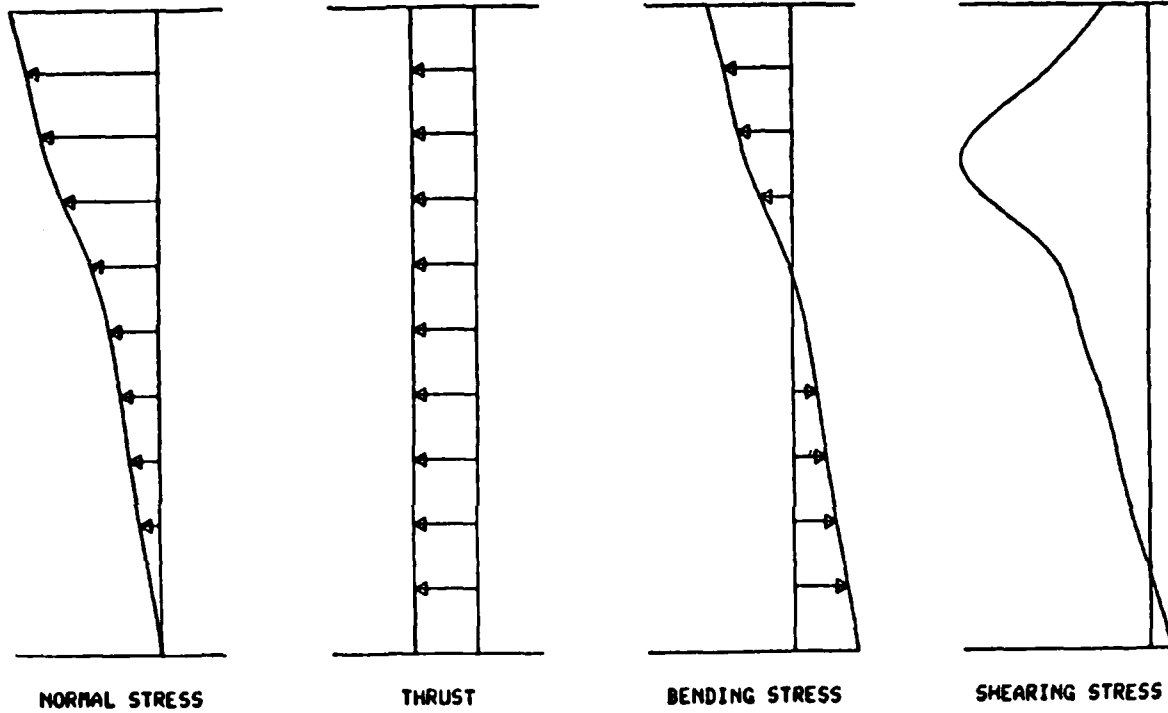
(X1, Y1) = (40 .14 )  
 (X2, Y2) = (54 .14 )  
 NEUTRAL AXIS = (46 62.14 )  
 SHEAR = 3323  
 MOMENT = -2 17  
 THRUST = - 7351

Figure A80. Load case 5A (section 6A)



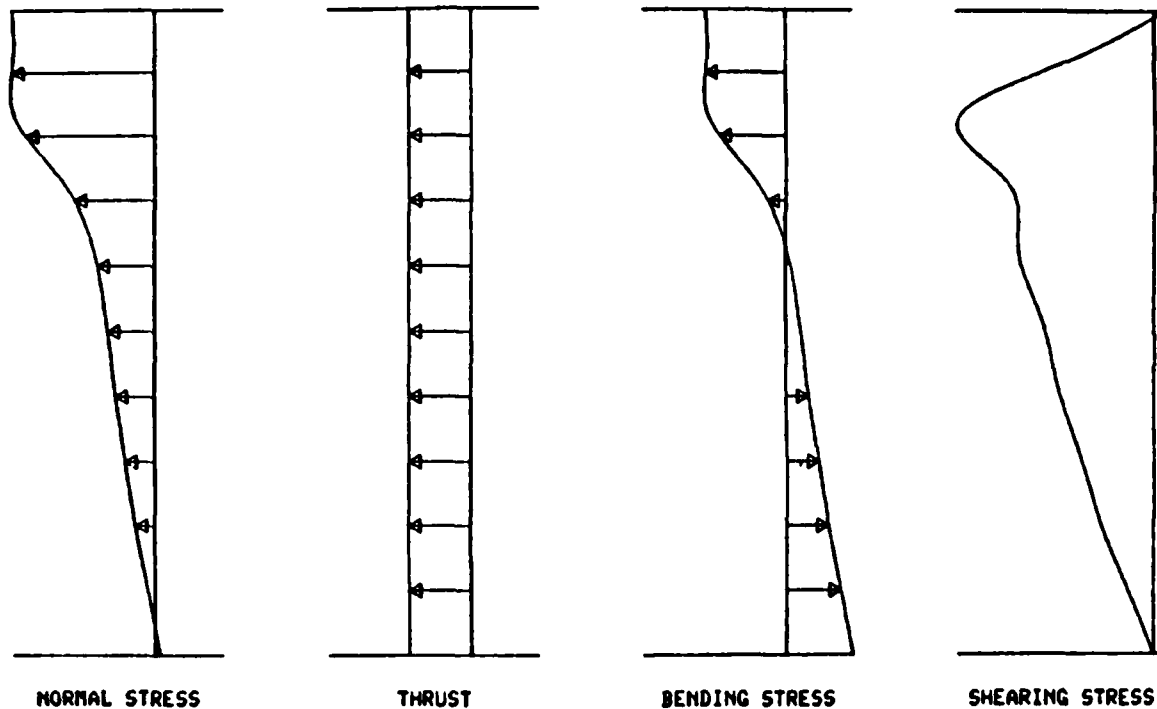
(X1, Y1) = (54 .1 )  
 (X2, Y2) = (54 .11 )  
 NEUTRAL AXIS = (54 .6 302 )  
 SHEAR = .0702  
 MOMENT = .4234  
 THRUST = - 3593

Figure A81. Load case 5A (section 7A)



(X1, Y1) • (63 .3 )  
 (X2, Y2) • (63 .11 )  
 NEUTRAL AXIS • (63 .7 437)  
 SHEAR • - 0887  
 MOMENT • 3746  
 THRUST • - 3095

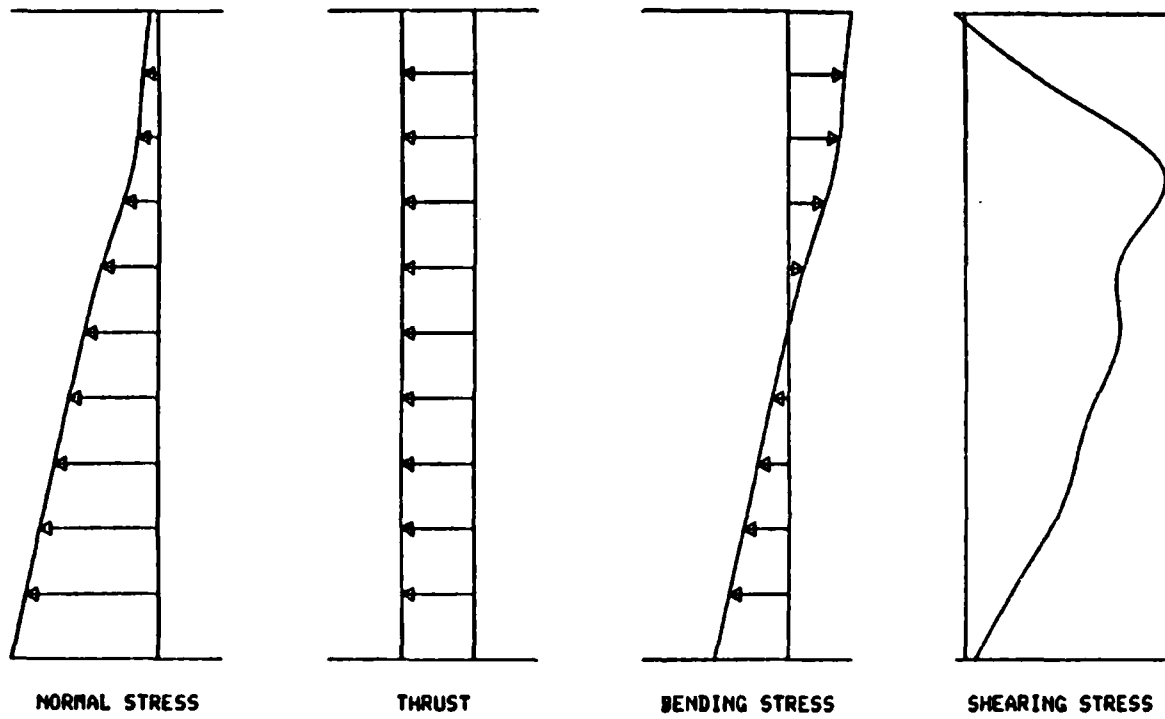
Figure A82. Load case 5A (section 8A)



(X1, Y1) = (40, -1)  
 (X2, Y2) = (40, 13)  
 NEUTRAL AXIS = (40, 7.544)  
 SHEAR = - 5148  
 MOMENT = 1 972  
 THRUST = - 7591

Figure A83. Load case 5A (section 9A)





(X1, Y1) = (40 .36 )  
 (X2, Y2) = (52 .36 )  
 NEUTRAL AXIS = (46 6.36.)  
 SHEAR = 0474  
 MOMENT = - 391  
 THRUST = - 2505

Figure A84. Load case 5A (section 10A)

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